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Development of an Adjustable Buoyancy Balloon Tracer of Atmospheric Motion Phase 3. Refinement of the Operational Prototype System

Sandia National Labs., Albuquerque, NM

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16. ABSTRACT

The adjustable buoyancy balloon tracer of atmospheric motion is a research tool designed to follow atmospheric flows in both the horizontal and the vertical. The design goals for the tracer balloon specify a lifetime > 3 days, tracking range > 1000 km, ceiling altitude > 5.5 km (500 mb), and capability to respond to mean vertical flows as low as 1 cm/s. The immediate motivations for this effort are to evaluate the accuracies of air pollution transport (trajectory) models used to establish source-receptor relationships to distances of order 1000 km, and to assess the limits on the predictability of source impacts at long distances. In Phase I of this project, the authors proposed a generic design for such a system, subjected the design to theoretical analysis, constructed a test-bed prototype, and conducted a series of tests with that prototype to evaluate the concept. In Phase II, the authors developed an operational prototype designed to meet the desired specifications. A limited number of test flights of the operational prototype were conducted. In Phase III of the project, improvements were made in electronic design, packaging, and in the remote command and data reception system. Two test flights were made, and while the results from these flights were inadequate to demonstrate that the design goals were met, the results were not inconsistent with that conclusion.

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DEVELOPMENT OF AN ADJUSTABLE BUOYANCY BALLOON TRACER OF ATMOSPHERIC MOTION

Phase III. Refinement of the Operational Prototype System

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ABSTRACT

An Adjustable Buoyancy Balloon Tracer of Atmospheric Motion is a research tool which allows one to follow atmospheric flows in both the horizontal and the vertical, including the weak sustained vertical motion associated with meso- and synoptic-scale atmospheric disturbances. The design goals for the Tracer Balloon developed here specify a lifetime $\geq$ 3 days, tracking range $\geq$ 1000 km, a ceiling altitude $\geq$ 5.5 km (500 mb), and the capability to respond to mean vertical flows as low as 1 cm/s. The Tracer Balloon is also to measure and telemeter selected meteorological variables, to be sufficiently inexpensive to permit use in significant numbers, and to be serviced by a ground system capable of handling several Tracers at a time. While the Tracer has applications throughout the atmospheric sciences, the immediate motivation for this effort is to meet the need to evaluate the accuracies of atmospheric transport models, to establish source-receptor relationships to distances of order 1000 km, and to assess the inherent limits on the predictability of source impact at long distances. In Phase I of this project, titled "Systems Design and Demonstration of Feasibility," the authors proposed a generic design for such a system, subjected the design to theoretical analysis, constructed a testbed prototype, and conducted a series of tests with that prototype to evaluate the concept. In Phase II of the project, the authors developed an operational prototype designed to meet the desired specifications. A limited number of short test flights of the operational prototype were also conducted. Flights were made using each of three control algorithms: constant pressure, constant potential temperature, and zero relative motion. Analysis of the data indicated that, in each case, the control system functioned properly. In Phase III of the project, the subject of this report, improvements were made in electronic design, packaging, and in the accompanying remote command and data reception system. In addition, two test flights were conducted. While the flight test program was inadequate to demonstrate that the design goals have been met, the results were not inconsistent with that conclusion. Currently, USEPA resources are not available to carry out the planned Phase IV of the project which would have involved continued testing and design changes to make the system more "user friendly." Support is being sought from other sources to further test and refine the system, and to put it to use.

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ACRONYMS

ADAS - Atmospheric Data Acquisition System

AGL - (Altitude) Above Ground Level

AIR - Atmospheric Instrumentation Research (Inc.)

ASCII - American (National) Standard Code for Information Interchange

CY - Calendar Year

CVB - Constant Volume Balloon

DOE - U. S. Department of Energy

EMI - Electromagnetic Interference

EPA - U. S. Environmental Protection Agency

FAA - Federal Aviation Administration

FAR - Federal Aviation Regulations

FY - Fiscal Year

HF - High Frequency

MSL - (Altitude Above) Mean Sea Level

NCAR - National Center for Atmospheric Research

NOAA - National Oceanic and Atmospheric Administration

PC - Personal Computer

PLT - Physical Lagrangian Tracer

PROM - Programmable Read Only Memory

PTT - Platform Transmitter Terminal (Argos)

RAM - Random Access Memory

USART - Universal Synchronous/Asynchronous Receive-Transmit (chip)

4 WD - 4 Wheel Drive (Vehicle)

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1. INTRODUCTION

An Adjustable Buoyancy Balloon Tracer of Atmospheric Motion is a physical Lagrangian tracer -- an airborne instrumentation system that follows the flow of air in its vicinity, and that can be tracked electronically. For decades, researchers have sought a Lagrangian tracer to aid in understanding the dynamics of the atmosphere. Advances in microelectronics, satellite communications, and battery technology have now made such a tracer system feasible. It addresses a broad need for a convenient means of following atmospheric flows.

The need for a physical Lagrangian tracer has led to extensive work with constant volume balloons (CVBs) which has been reviewed by Tatom and King (1977) and by Zak (1983). CVBs follow the horizontal motions of the volume of air in which they are embedded, but not the vertical motions. Coupled with wind shear, this characteristic limits their usefulness. Inability to follow vertical air motions leads to eventual displacement in the vertical from any specific air mass one wishes to follow. In the presence of wind shear, the air in the vicinity of the vertically-displaced CVB is moving at a different speed and direction from the air mass to be traced.

Physical Lagrangian tracers are necessarily balloon-borne systems, and consequently must operate under Federal Aviation Regulations Part 101: Moored Balloons, Kites, Unmanned Rockets, and Unmanned Free Balloons (USGPO, 1987). The purpose of this regulation is to strictly limit the hazard to air navigation which such systems might otherwise represent. Under this regulation, the U.S. weather services, together with the weather services of other nations around the world coordinated by the World Meteorological Organization, routinely launch hundreds of radiosonde balloons twice daily. Radiosondes measure the meteorological conditions aloft from the surface to beyond 20,000 m above many major airports and other selected sites.

It is an explicit design goal that the Tracer Balloon operate under the exemption clauses of FAR 101, as do radiosondes. Under these clauses, if a balloon system carries a payload which meets certain conditions regarding weight, density, and strength of suspension, the system is exempt from most of the other provisions of the regulation. This is important principally because one of those other provisions precludes operating non-exempt balloon systems in clouds, or even in the vicinity of clouds. This provision would severely limit the usefulness of a Tracer Balloon which was not exempt.

Because safety is an important consideration, safety features are incorporated in the Tracer Balloon design beyond those specified by FAR 101. When the Tracer Balloon is flown higher than 300 m (1000 ft) above ground level, it carries an FAA transponder with encoding altimeter. Thus FAA Air Traffic Controllers see the Tracer on radar as prominently as a commercial airliner. It also carries a corner-type radar reflector and high visibility markers. When it is flown at night, it will carry a strobe light.

The intended uses provide other Tracer Balloon design goals:

- Lifetime $\geq$ 3 days.
- Tracking range $\geq$ 1000 km.
- Telemetry of relative vertical air motion, pressure, temperature, and humidity.
- Ground system capable of handling several Tracer Balloons at a time.

- Capable of establishing specified ascent and descent rates under radio command.
- Capable of reaching altitudes up to 5.5 km (500 mb).
- Capable of following mean vertical flows as low as 1 cm/s with acceptable fidelity.
- Sufficiently inexpensive to permit use in significant numbers on an expendable basis.

The project was to be divided into four phases:

Phase I:	Systems Design and Demonstration of Feasibility.
Phase II:	Development of an Operational Prototype.
Phase III:	Refinement of the Operational Prototype System.
Phase IV:	Addition of Elements Necessary to Create a Practical Research Tool.

Phase I was initiated in fall, 1983, and ran through calendar year 1984. The results were reported by Zak et al (1986). The Phase I report gives the chain of reasoning and the experimental data which led to the original operational prototype design. Phase II spanned calendar year 1985. The results were presented by Zak et al (1987). Phase III began in late spring of 1986, and extended through 1987. Resource constraints severely limited the Phase III test program. At the present time, USEPA resources are not available to support Phase IV. Interest in the Tracer Balloon from other programs, however, makes it likely that the project will continue.

2. DESIGN CONCEPT

Balloon systems obey Archimedes' Principle: A body immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced. Thus a balloon system will be in equilibrium when the weight of the air it displaces is equal to the weight of the system.

For a CVB the equilibrium condition is met only at one well-defined altitude, and the CVB seeks that altitude. If it is above the equilibrium altitude, the CVB experiences a net downward force due to gravity because the ambient air is less dense at the higher altitude, and the volume of air displaced is fixed. Likewise, if it is below its equilibrium altitude, it experiences a net upward force, since the buoyancy force exceeds the gravitational force. Thus, CVBs tend to oscillate around their equilibrium altitude, the oscillations driven by atmospheric turbulence. In atmospheric flows which have zero average vertical velocity, CVBs naturally follow the horizontal flow at their equilibrium altitude. However, in flows in which the vertical component is significant, a CVB will not adequately follow the overall flow.

The Tracer Balloon is a modified CVB. It is designed to sense its deviation from the mean vertical flow, and to adjust its buoyancy to keep its average vertical motion relative to the air surrounding it near zero. Thus, the Tracer follows both horizontal and vertical flows.

The buoyancy adjustment principle used in the Tracer was first put forward by V. E. Lally of the National Center for Atmospheric Research (NCAR) more than twenty years ago (Lally, 1967). He proposed a CVB with an inner bladder, or ballonet, to contain the lift gas (helium). The remainder of the CVB was to be filled with air (Figure 2-1). A system of pumps and valves was included to allow air to be pumped in or to be released, respectively increasing the mean density of the balloon and thereby decreasing its equilibrium altitude, or decreasing the

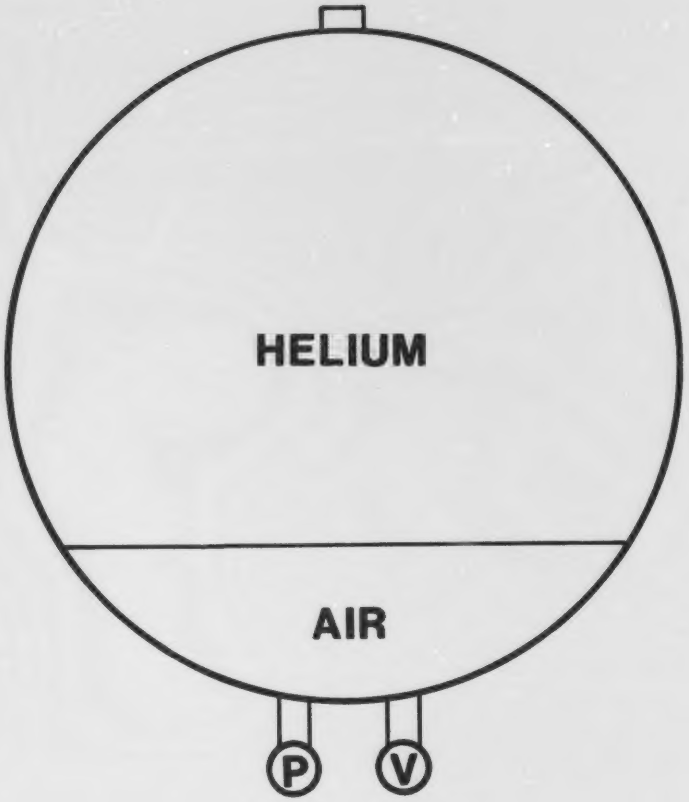


Figure 2-1. Buoyancy Adjustment Principle. The outer skin of the balloon is made of a material which expands very little as the internal pressure increases. A thin polyethylene inner balloon, or "ballonet" keeps the helium lift gas separate from the air ballast. A pump (P) permits more ballast air to be taken on. A valve (V) permits ballast air to be vented. The total volume remains nearly constant, so pumping or valving changes the average density of the system, and hence its altitude.

mean density and thus increasing the equilibrium altitude. Lally's concept was adopted for the Tracer Balloon. Previously, it had been tried by the French on stratospheric balloons with some success, but was not developed further (Blamont et al, 1974).

To have a workable Tracer, it is also necessary to incorporate a means of sensing deviation from the mean vertical air flow. Two options are available. The first is to measure the vertical air velocity relative to the Tracer Balloon, and to integrate that velocity with time to obtain relative vertical displacement. The second is to take advantage of the near-adiabatic nature of atmospheric flows, and to use potential (or equivalent potential) temperature as the control parameter.

The first approach places very stringent demands upon the vertical velocity measurement. If the measurement involves an average systematic bias of only 1 cm per second consistently in the same direction, the control system will create a relative vertical displacement which grows linearly with time at the rate of 36 m/hour. On the other hand, if the same 1 cm/s error is entirely random, the total expected error in a 72 hour flight may be less than 40 m (Zak et al, 1986). Presently, it is believed that while it is probably feasible to use relative vertical motion to control the tracer for several hours, it is probably not acceptable for continuous use over 3 days.

Use of the near-adiabatic character of atmospheric flows poses less of a measurement problem. In the absence of liquid water and of diabatic heating or cooling, the potential temperature is conserved -- that is, trajectories are isentropic (Holton, 1979). Potential temperature is given by:

$$\theta = T(1000/P)^{R_a/c_p} \qquad (2\text{-}1)$$

Here T is the ambient temperature, P the ambient pressure, R_a the gas constant for unsaturated air, c_p the specific heat at constant pressure for air, and $R_a/c_p = .286$. In a standard atmosphere, the vertical gradient of potential temperature at sea level is 3.3×10^{-3} degrees Kelvin per metre. So, if one controls potential temperature in an atmosphere with this lapse rate to plus or minus a tenth of a degree, the altitude would be controlled to ±31 m, quite adequate for our purposes.

However, diabatic effects do occur. In the region of interest below 5.5 km, they are strongest near the surface, and decrease with height above ground. Throughout most of the troposphere, diabatic heating and cooling are of order one degree Kelvin per day (Wallace and Hobbs, 1977). Depending upon meteorological conditions, this change may be net heating, net cooling, or interim variation with no net gain or loss. In the absence of a means of taking these effects into account, they would limit the accuracy with which an isentropic Tracer Balloon would reflect air motion.

In the presence of liquid water, condensation and evaporation occur with the result that potential temperature is no longer conserved even if the flow is adiabatic. However, in the absence of precipitation, "equivalent potential temperature" is conserved in wet processes (Holton, 1979; Wallace and Hobbs, 1977). It could be used as the altitude control parameter in the presence of cloud. The equivalent potential temperature is given by:

$$\theta_e \simeq \theta \exp\,(Lq_s/c_pT) \qquad (2\text{-}2)$$

where L is the latent heat of condensation, and q_s is the saturation mixing ratio of water vapor in air at the ambient temperature and pressure. An even more general formulation of potential temperature is available which may prove useful (Hauf and Hoeller, 1987).

The operational prototype currently incorporates three control algorithms selectable by radio command. The control parameters for these algorithms are, respectively, relative vertical displacement, potential temperature, and ambient pressure. In a stable (non-convective) atmosphere, in the absence of liquid water, the potential temperature control algorithm is most appropriate. In a stable but saturated atmosphere, an algorithm yet to be written using equivalent potential temperature would be most appropriate. In a convective atmosphere, the gradient of the potential temperature with altitude goes to zero. Hence, under convective conditions, potential temperature is not a satisfactory control parameter. Rather, relative vertical displacement becomes the control parameter of choice. Under convective conditions, over reasonably flat terrain, even the constant pressure control algorithm may be satisfactory, since under those conditions, the entire convective layer is well mixed.

The question of the most appropriate control strategy to adopt under different meteorological conditions is quite complex. It was discussed at some length in the Phase I report, especially in Appendix J (Zak et al, 1986). It is an area that will need to receive continued attention as the Tracer Balloon comes into use.

Appendix A contains a summary of the equations from Phases I and II which describe the operation of the Tracer Balloon.

3. MODIFIED OPERATIONAL PROTOTYPE DESIGN

The purpose of this section is to describe the modified operational prototype Tracer as it existed at the completion of Phase III in sufficient detail to facilitate the efforts of other researchers who may wish to follow.

a. Balloon Envelope

A second generation balloon envelope had been designed during Phase I. However, first generation balloons remained from the original order of seven even after the completion of Phase II. Hence, first generation balloons were used in Phase III. They were designed and fabricated to meet our needs by Raven Industries of Sioux Falls, South Dakota. Their nominal characteristics are:

Shape: 12 Gore Sphere
Volume: 12.0 m^3
Diameter: 2.9 m
Material: 3.0 mil polyester (bilaminated)
Ballonet: 1.0 mil polyethylene
Weight: 4.4 kg

Gores are the almond-shaped pieces into which flat material must be cut in order to form a sphere when they are joined edge to edge. The inner polyethylene balloon, or ballonet, is attached to the outer polyester (mylar) balloon only at a helium fill fitting located at the top. The bottom fitting is a 19 cm diameter external nylon plate fastened with screws to a nylon ring inside the outer balloon. The nylon plate was modified to accept two fittings for air lines, and electrical leads to accommodate a pressure sensor assembly inside the balloon. A larger fitting, blanked off in flight, was also installed on the bottom plate to permit more rapid inflation and deflation than could be accomplished through the small fittings which were connected to the valves which also mounted on the bottom plate (Fig. 3.1). The bottom plate can be removed, leaving an 11.4 cm aperture which provides access to the inside of the outer balloon.

In the testbed prototype constructed for Phase I, the top fitting on the balloon was closed by a simple screw-on cap. In the operational prototype, a mating fitting was added that incorporated a pair of cutdown devices, and a helium fill line made of "layflat" polyethylene tubing. In Phase III, the layflat was replaced with rubber surgical tubing because the layflat was found likely to leak. In the cutdown device, a polyethylene membrane stretched across an aperture forms a seal for the helium. The fixture holding the polyethylene in place is a commercially available sample cell for spectroscopic use (Part No. 1530) obtainable from Chemplex Inc. A pair of electric matches are mounted adjacent to the polyethylene in such a way that if either one is actuated, a hole is burned in the membrane, and the helium is allowed to flow out. This results in a controlled descent (Appendix A). The flame from the electric match is contained within the cutdown device, and is comparable to that from a conventional match. However, after the electric match fires, there is no residual flame. Electric matches of this type are obtainable from explosives dealers, and cost about a dollar each.

The first generation balloons as received from Raven were found to have a number of troublesome flaws. In three of the seven balloons, the inner polyethylene ballonets leaked badly, and had to be removed, repaired, and reinstalled. They were

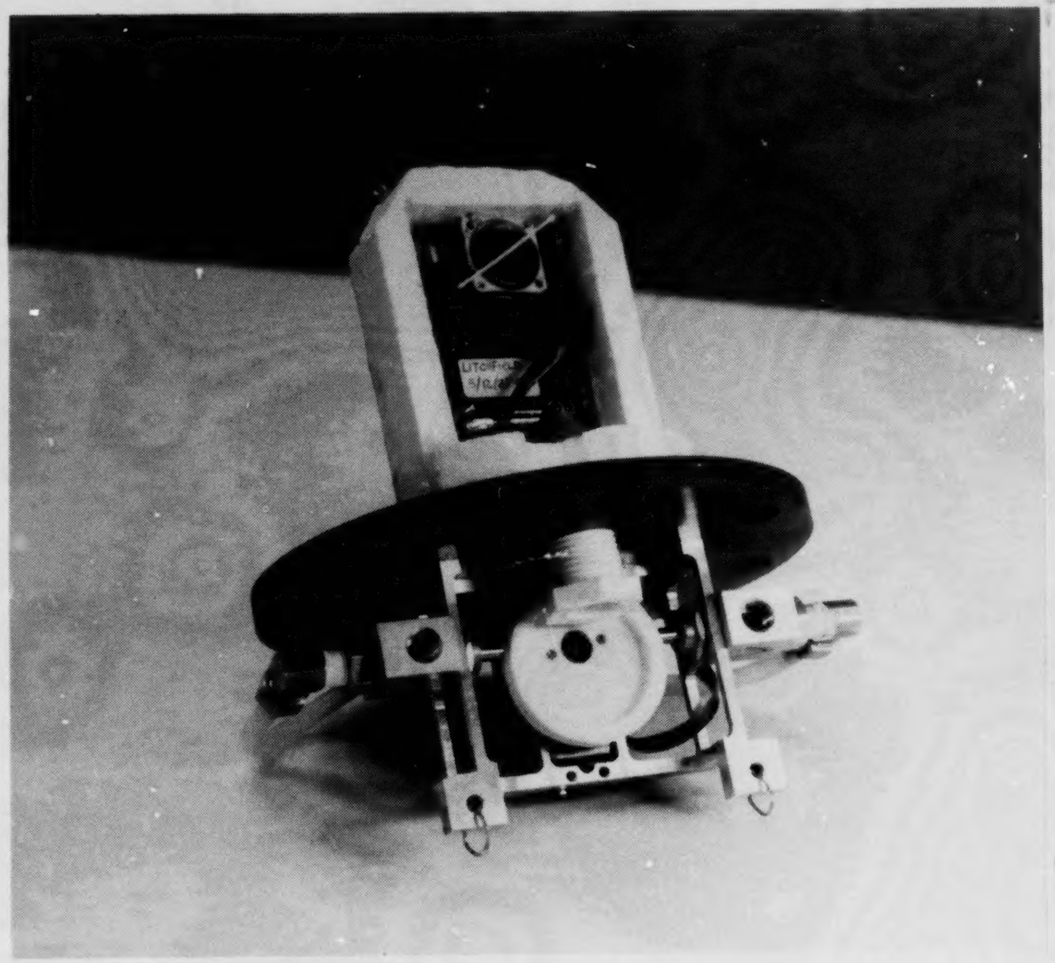


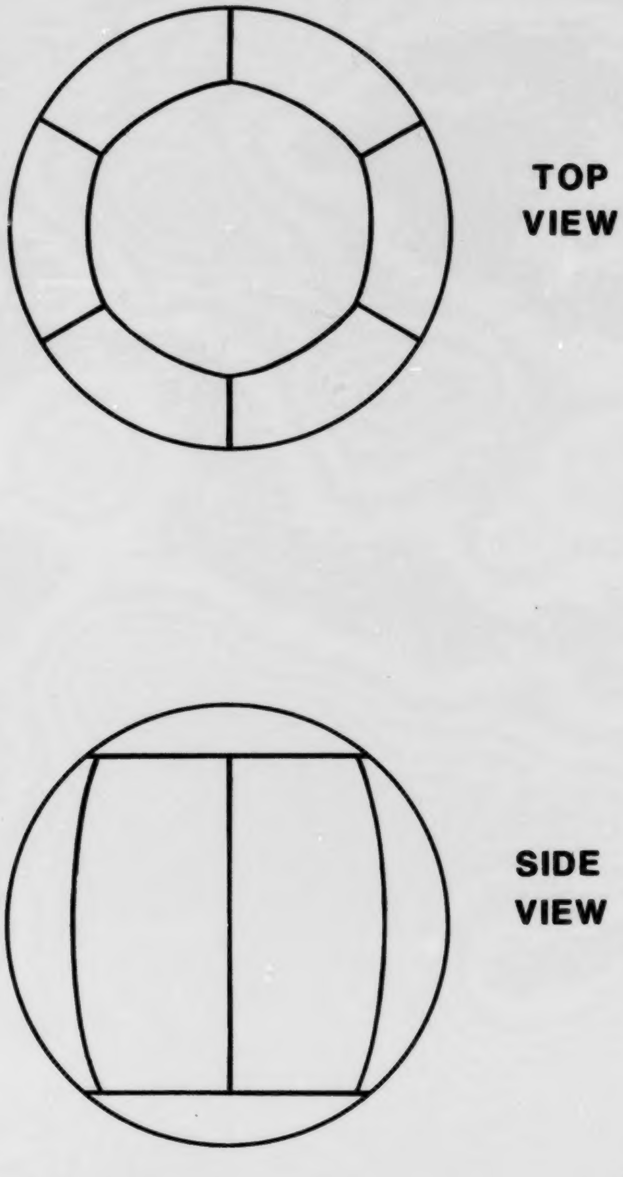
Figure 3-1. Bottom Plate with Valves and Servo. Note the internal sensor assembly on the inner surface of the bottom plate.

apparently damaged during installation in the outer constant volume balloon during the manufacturing process. The top fitting and the bottom plate both required disassembly, application of sealant, and reassembly in order to be adequately leak tight. Vacuum grease was used at the top fitting. Silicone rubber sealant (GE Silicone II) was used at the bottom plate. At the top of the outer constant volume balloon, the gores are heat-sealed to a circular piece of mylar about 25 cm in diameter which held the fitting for filling the inner balloon at its center. The seal between the gores and the mylar top piece was responsible for several leaks, and partially failed in the case of two balloons. On the last flight, this seam was reinforced with shipping tape and painted over with silicone sealant. Finally, the load patches on the balloons were found to be too easily damaged or even torn off if the lines attached to them which support the payload were used to handle the balloon in any but light winds. Consequently, a girdle made of Kevlar line was attached to the balloon for ground handling and left in place for flight (Fig. 3.2). Kevlar has a very high strength to weight ratio. The Kevlar line used here was tether line obtained from AIR, Inc.

b. Payload

The operational prototype payload consists of the following elements:

- Buoyancy adjustment subsystem
- Sensor subsystem
- Microcomputer
- Interfaces
- Cutdown timer
- Argos platform transmitter terminal
- Argos antenna
- Radio command receiver
- Command decoder



TOP VIEW
SIDE VIEW

Figure 3-2. Kevlar Girdle for Balloon Handling.

- Command antenna
- Tracking aids
- Batteries

Each of these elements is discussed below. A block diagram of the payload is given in Figure 3-3. Detailed schematic diagrams and parts lists are given in Appendix C. An assembly drawing of the modified operational prototype Tracer is given in Figure 3-4.

The buoyancy adjustment subsystem is shown in Figure 3-5. It makes use of three of the same type of Gilian pumps used in Phases I and II. Gilian makes a range of different pumps for different applications. They look identical. Hence, it was found necessary to measure the flow rate on each pump at the nominal operating voltage of 7.2 V (two lithium cells in series) before incorporation into the pump package. The pumps we used each generated a flow of about 6 lpm when pumping against zero head at this voltage, and a flow of about 4 lpm when pumping against a 90 mb superpressure through the valve system. Gilian lists them as 6 V pumps. The pump package was mounted directly below the baseplate.

The same Klippard valves as in Phases I and II were also used in the Phase III buoyancy adjustment subsystem. However, here the valves were mounted directly on the baseplate, rather than in a payload package well below the balloon. This is similar to design practice for larger balloon systems, where valves are normally mounted on a plate, usually at the top, which is an integral part of the balloon envelope. For the purposes of FAR 101, this makes the valves and their drive mechanism formally part of the balloon, rather than part of the payload. The drive mechanism is the servo and cam mechanism shown in Figure 3-1. The baseplate and valve assembly was designed and fabricated by Albuquerque machinist D. Ivey.

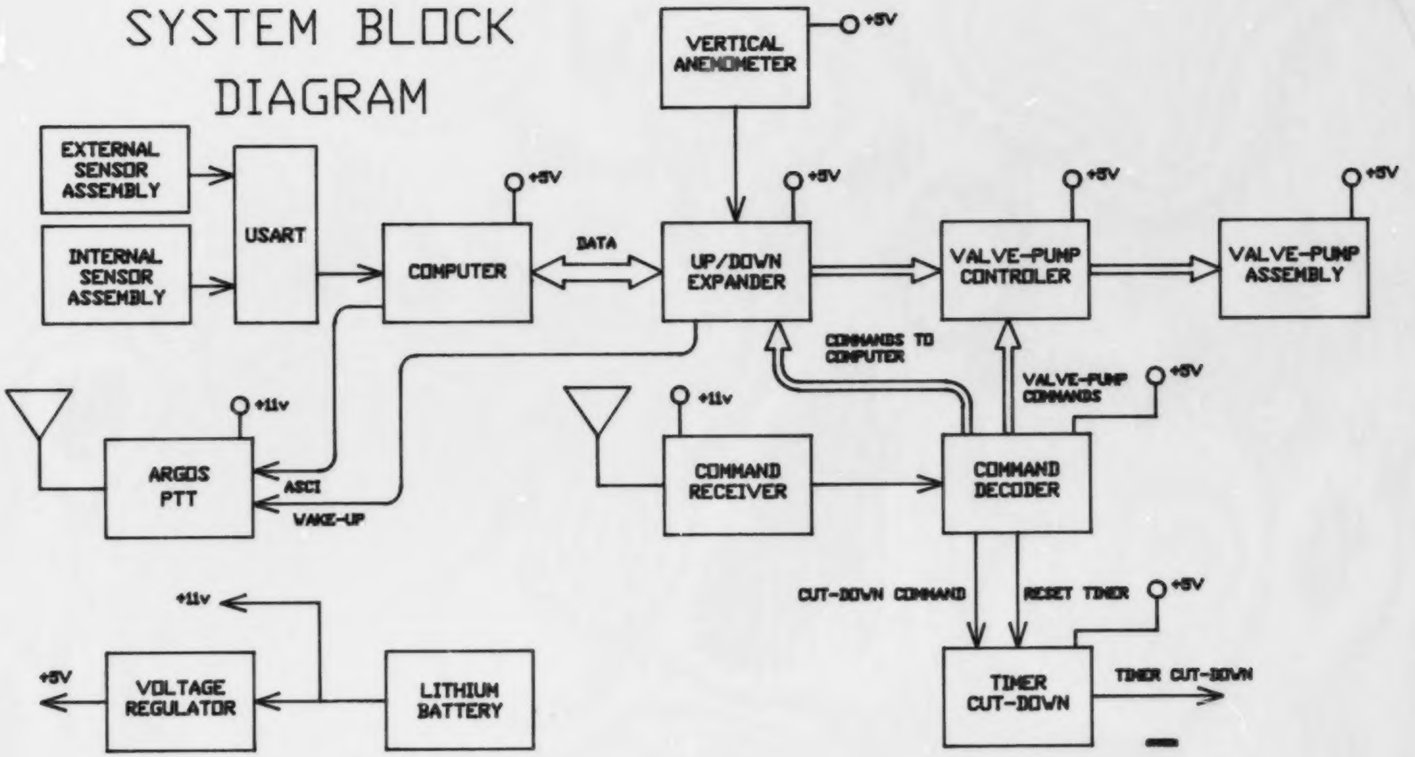

SYSTEM BLOCK DIAGRAM
EXTERNAL SENSOR ASSEMBLY
INTERNAL SENSOR ASSEMBLY
USART
COMPUTER
+5V
DATA
VERTICAL ANEMOMETER
+5V
UP/DOWN EXPANDER
+5V
VALVE-PUMP CONTROLER
+5V
VALVE-PUMP ASSEMBLY
+5V
COMMANDS TO COMPUTER
VALVE-PUMP COMMANDS
+5V
+11v
ARGOS PTT
ASCI
WAKE-UP
+11v
COMMAND RECEIVER
COMMAND DECODER
CUT-DOWN COMMAND
RESET TIMER
+5V
TIMER CUT-DOWN
TIMER CUT-DOWN
+11v
+5V
VOLTAGE REGULATOR
LITHIUM BATTERY

Figure 3-3. Block Diagram of the Phase III Payload.

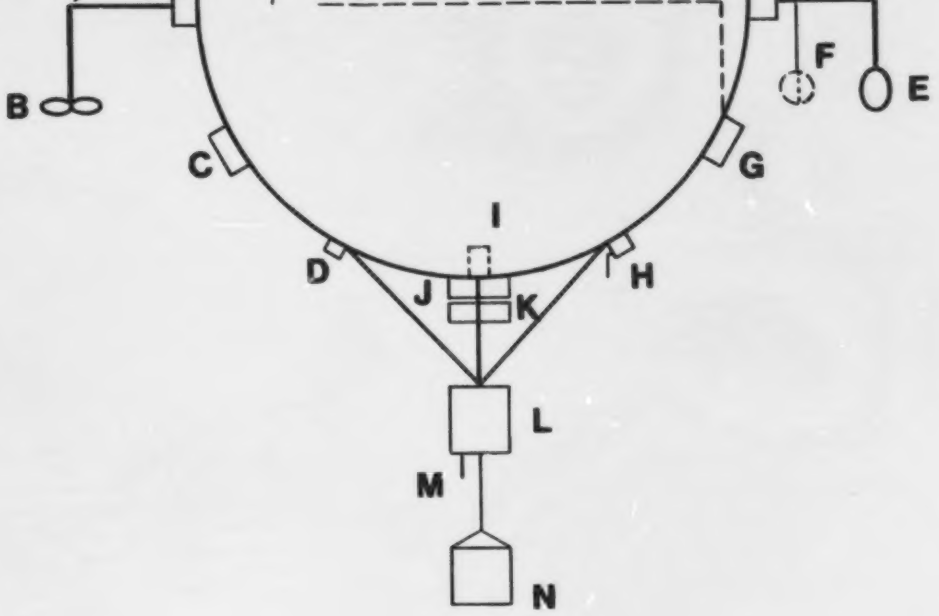
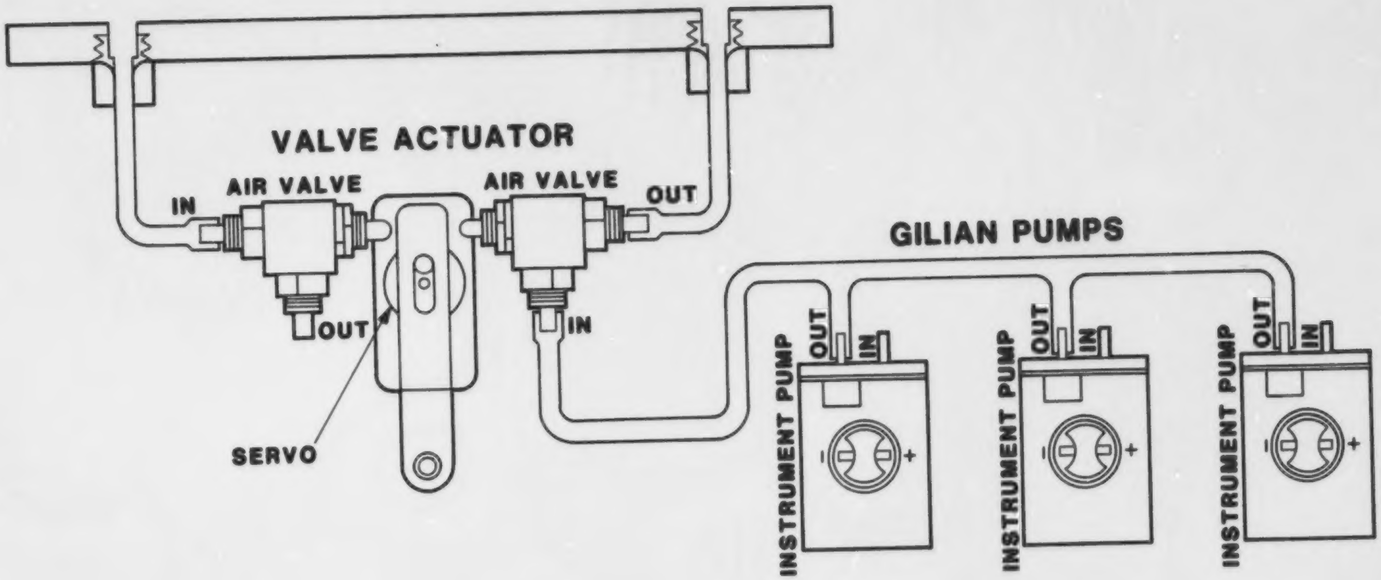


Figure 3.4. Assembly Drawing of the Phase III Tracer Balloon. A. Top fitting with cutdown device and helium fill line; B. Vertical anemometer; C. Cutdown timer; D. Recovery beacon; E. External sensor assembly; F. Radar corner reflector; G. Radio command receiver; H. Independent airsonde; I. Internal sensor assembly; J. Bottom plate with valves and servo; K. Pump box; L. Main electronics package; M. Argos antenna; N. FAA transponder package.


VALVE ACTUATOR
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IN
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Figure 3-5. Buoyancy Adjustment Subsystem.

The sensor subsystem consists of three elements. The first is an aspirated sensor assembly which measures ambient pressure, temperature, and humidity. It is a modified AIR Inc. prototype digital radiosonde. The assembly outputs data in ASCII format. The transmitter normally in place has been deleted, and the assembly has been housed in a styrofoam package normally used for a tethersonde, rather than a radiosonde. The tethersonde package makes provision for aspiration. Aspiration is important in the Tracer Balloon application because inadequate natural ventilation takes place.

Between Phases II and III, AIR Inc. changed the format of the serial output for its prototype digital sonde. This relatively minor change could not be easily accommodated in the Tracer software which at that time exclusively used interpreted BASIC. The problem was overcome by procuring special units from AIR with the original data format.

The second element of the sensor subsystem is a second modified digital AIR sensor assembly mounted on the inside of the baseplate to report pressure and temperature within the balloon. No aspiration was provided for this unit.

The third element of the sensor subsystem is the vertical anemometer. It makes use of a stock 22.9 cm (9 in) diameter expanded styrofoam Gill propeller from R. M. Young Inc., and a slightly-modified Spaulding Instruments C1 rotation sensor. The Spaulding sensor is a photoelectric type which gives both rate and direction of rotation. It is modified only in that dust seals normally present were removed to minimize friction. An anemometer of this type was originally designed for Sandia by MacCready (1981). It has a starting speed under 2 cm/s, and a measurement threshold of under 3 cm/s. This starting speed and low velocity performance should allow relative vertical velocity measurements averaged over minutes to be made down to 1 cm/s or less. Even at very low intensities of turbulence, the instantaneous relative vertical air velocities are likely to be considerably higher than the average over a few minutes. The sensor package and the vertical anemometer are shown in Figure 3-6. It should be mentioned that for Phase III, additional Spaulding rotation sensors were obtained. The new sensors showed considerably more friction than the original units, and higher starting speeds for the vertical anemometer. Hence, the original units were used instead. Apparently, Spaulding has gone to a lower quality bearing in its standard sensors. For future payloads, units with the original high quality bearings will be required.

The heart of the control system is an Intel 8052AH BASIC microcomputer. The Phase II operational prototype contained 4 K bytes of random access memory (RAM) and 4 K bytes of programmable read only memory (PROM). This was found to be marginally adequate at best. The control program had to be kept as simple as possible to fit the available memory. In the Phase III modified operational prototype, the memory was increased to 16 K bytes. The original 8052AH was also replaced with an updated version which does not automatically convert lower case ASCII characters into upper case. This feature had caused problems in the Phase II system. The control program is written primarily in MCS BASIC-52, the interpreted BASIC which is the language of the 8052AH. It was entered into the microcomputer from a terminal. After testing, it was transferred to PROM. Thereafter, when the payload was powered up, the program self-loaded and ran. In the middle of Phase III, it was found necessary to include one machine language subroutine to read the sensors reliably without errors. In the Phase II system, it now appears that errors occurred, but were rare. In the more complicated control program used in Phase III, program timing

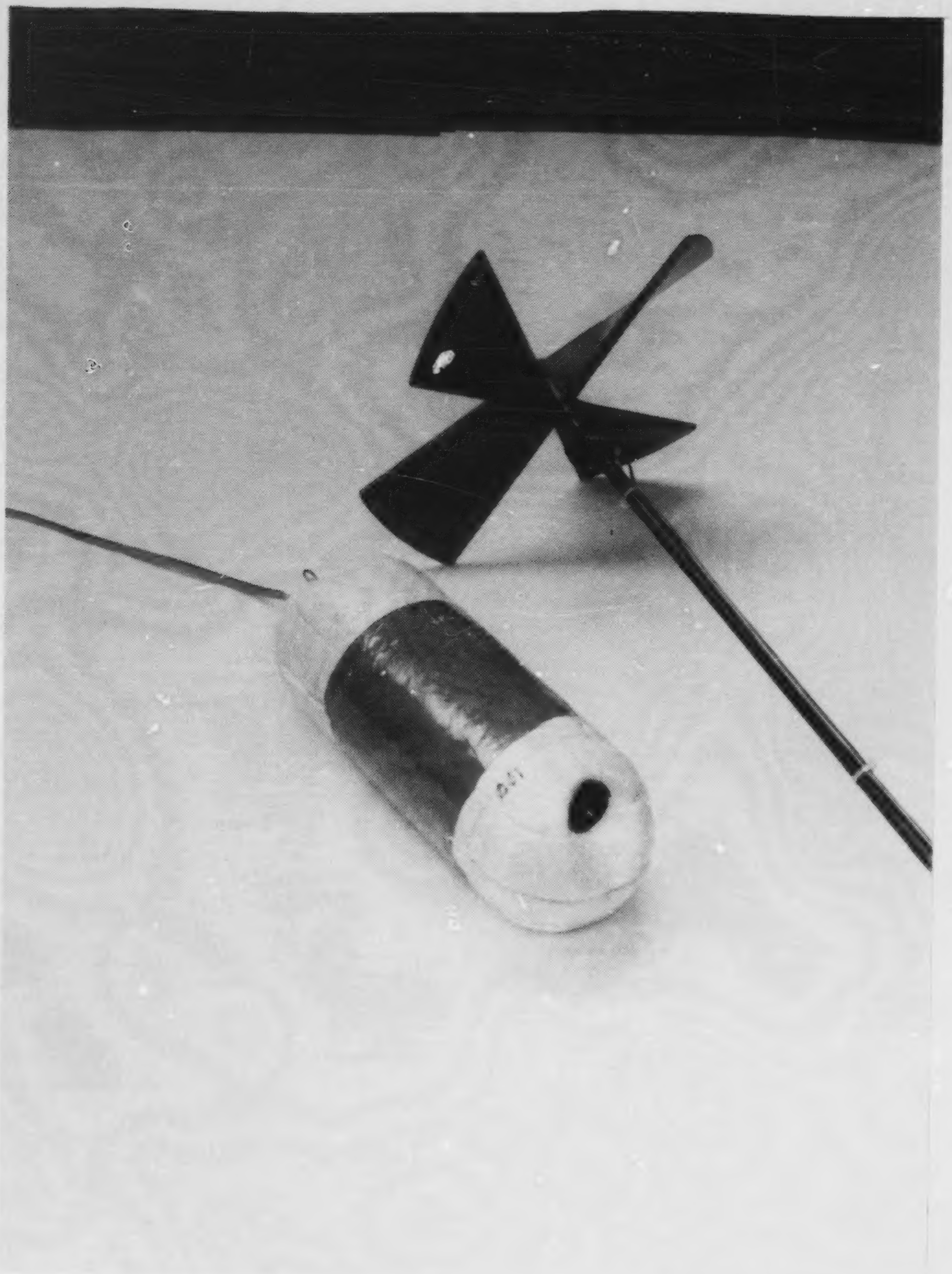

Figure 3-6. Vertical Anemometer and External Sensor Assembly.

exacerbated the error problem. Inclusion of a USART (Universal Synchronous/Asynchronous Receive Transmit) chip and a machine language subroutine to service it completely eliminated the problem. A listing of the control program used during the January field test is given in Appendix D.

The Intel 8052AH requires a variety of interfaces to other system elements. Those interfaces are combined on the same board with an up-down counter which is part of the vertical anemometer.

The cutdown timer automatically actuates the cutdown device after a preselected period. However, the timer can be reset to zero by radio command. In normal operation, the timer reset command is sent at regular intervals. As long as those commands are received at intervals not exceeding the preselected period, automatic cutdown is avoided. If, on the other hand, radio communication with the Tracer is lost for a period exceeding that which has been preselected, the Tracer is automatically removed from the sky. This arrangement avoids the possibility of the Tracer becoming a derelict in the event that radio communication is lost. In Phase III, a modified design of the cutdown timer was adopted (Appendix C). Here it was attached with adhesive-backed velcro tape to the skin of the balloon just below the equator.

The Argos platform transmitter terminal (PTT) was made by Telonics, of Mesa, Arizona. It is uniquely compatible with the flight control microcomputer. It is controlled by ASCII input commands. The first ASCII byte specifies the identification code of the PTT and the way the data are to be processed for transmission. The next 32 bytes are the data to be transmitted. Eight codes are programmed into each PTT. The computer controls which code or codes are used. The Argos data frame used here is given in Appendix E. As in Phase II, the Argos PTT was part of the main electronics package. In Phase II, the Argos antenna was a high gain device designed originally at NCAR for use on high altitude balloons. It was found that the radiation pattern and polarization of this antenna made data reception at the ground difficult at longer distances. Hence it was replaced by a matched stub antenna sold by Telonics. A detailed description of the entire Argos satellite-based data collection and platform location system was included in the Phase I report as Appendix H (Zak et al, 1986).

The radio command receiver is a unit designed and built for our application by Hock Engineering of Boulder, Colorado. It operates on 13.8035 MHz, a frequency to which Sandia has access. It has sub-microvolt sensitivity. In Phase III, the receiver was attached to the skin of the balloon with Velcro in a position symmetrically located relative to the cutdown timer. The command receiver antenna is a quarter wavelength wire now also attached to the skin of the balloon, rather than left to trail below.

The commands are electronically encoded at the transmitter, and decoded at the receiver. In Phase II, the encoder/decoder circuit pair were commercially available components designed for use in television remote control systems. This command system was found to be highly vulnerable to electronic noise. In the presence of even low levels of noise, the decoder would not recognize transmitted commands. Hence, the effective range of the command system was limited to a couple of miles -- not at all acceptable. The command code was changed to a much more noise resistant one which involves sequences of combinations of audio tones (Dual Tone Multi-Frequency Coding). This coding is commonly used in telecommunications systems. It was modified to be even more noise resistant by requiring that the same pair of tones be present on multiple interrogations in order for the tone pair to be considered valid. This command system functions properly even when the the signal is several db below the noise. This system was adopted after several other commercially available coding schemes were tried. The commands currently available are:

- -Activate cutdown
- -Reset cutdown timer
- -Turn on pumps
- -Open valve
- -Initiate control in pressure mode
- -Initiate control in potential temperature mode
- -Initiate control in relative vertical motion mode
- -Decrement current value of control parameter
- -Increment current value of control parameter

The encoder/decoder pair is capable of incorporating more commands with minimal changes.

In Phase II, a redundant command cutdown package was mounted near the balloon top fitting. It made use of a model aircraft radio control receiver to actuate one of the electric matches on command independent of the cutdown timer and the main command system. In Phase III, however, it was found that this system was quite vulnerable to activation by electromagnetic interference (EMI). On the first attempt to launch the Phase III system, the cutdown device spuriously fired twice before it was realized what was happening, and the second cutdown package disabled. This vulnerability was not detected during the Phase II test flights because those flights took place in a remote area with a relatively benign EMI environment. The Phase III test flights were launched from an airport where a variety of transmitters were in intermittent use.

Even without the second cutdown package, there are still three ways to bring the balloon down. The first is to use the cutdown command; the second is to turn the pumps on and to leave them on until the balloon reaches the ground; the third is to allow the cutdown timer to run out.

The tracking aids were not flown on the operational prototype Tracer during the short flights conducted during Phase II. Consultation with the FAA suggested that for flights under 300 m above ground level (AGL) in the test area, there was no need for them. On both Phase III flights, however, a corner-type radar reflector was flown, and on the second such flight which was not limited to 300 m, an FAA transponder with encoding altimeter made by Terra Corporation of Albuquerque was also flown. This unit appears to be the lightest and lowest power drain transponder on the market. Thus far, no night flights have been carried out. Hence, a strobe has not been flown. However, a strobe (manufacturer unknown) designed for use on ship masts appears to be quite suitable provided that it is repackaged. It is designed to work on 12 VDC, but in fact will function on a supply voltage as low as 7 VDC. It functions well on a 9 V Kodak lithium battery. Without the very heavy plastic case, the strobe itself weighs 70 g. In actual use, it would need to be turned on during the nighttime hours by a photocell light level sensor.

On the first Phase III flight, a Telonics radio beacon designed for animal tracking was flown to aid in payload recovery. On both flights, a standard AIR 403.5 MHz airsonde was also flown velcroed to the balloon skin to aid in balloon tracking. It was used in conjunction with an AIR Atmospheric Data Acquisition System (ADAS) ground station and an optical theodolite equipped with shaft encoders. This permitted the trajectory of the Tracer Balloon to be accurately recorded as long as it remained in view of the launch point.

The batteries used in both Phases I and II were lithium thionyl chloride units in AA, C, and D cell sizes procured from Altus Inc. They are reported to have good low temperature characteristics. This property will be necessary in order to meet the 5.5 km (500 mb) altitude design goal. At this altitude, temperatures down to about -25 C will be encountered. Tests with the batteries have been conducted down to -18 C.

There was evidence in Phase III, however, that at the present time even at 0 C these batteries do not have their rated capacities. The batteries used on both Phases II and III were purchased in 1985. Hence, they were more than two years old. It is not clear if the decreased capacity problem is a matter of shelf life, low temperature performance, or a combination of both. In any case, further work on battery performance is warranted.

The main electronics package is shown in Figure 3-7. The cutdown timer, pump box and command receiver are shown in Figure 3-8.

c. Command and Data Reception System

A block diagram of the command and data reception system used in Phase III is shown in Figure 3-9. It consists of a Handar Argos uplink receiver and decoder, an IBM compatible PC (NEC APCIII), a command encoder and interface package, an ICOM Model 745 transceiver with FM option and an antenna coupler (B&W, model No. VS300A). For the first Phase III flight, the command and data reception system was mounted in a 5 m Airstream trailer (Figure 3-10). For the second flight, it was mounted in

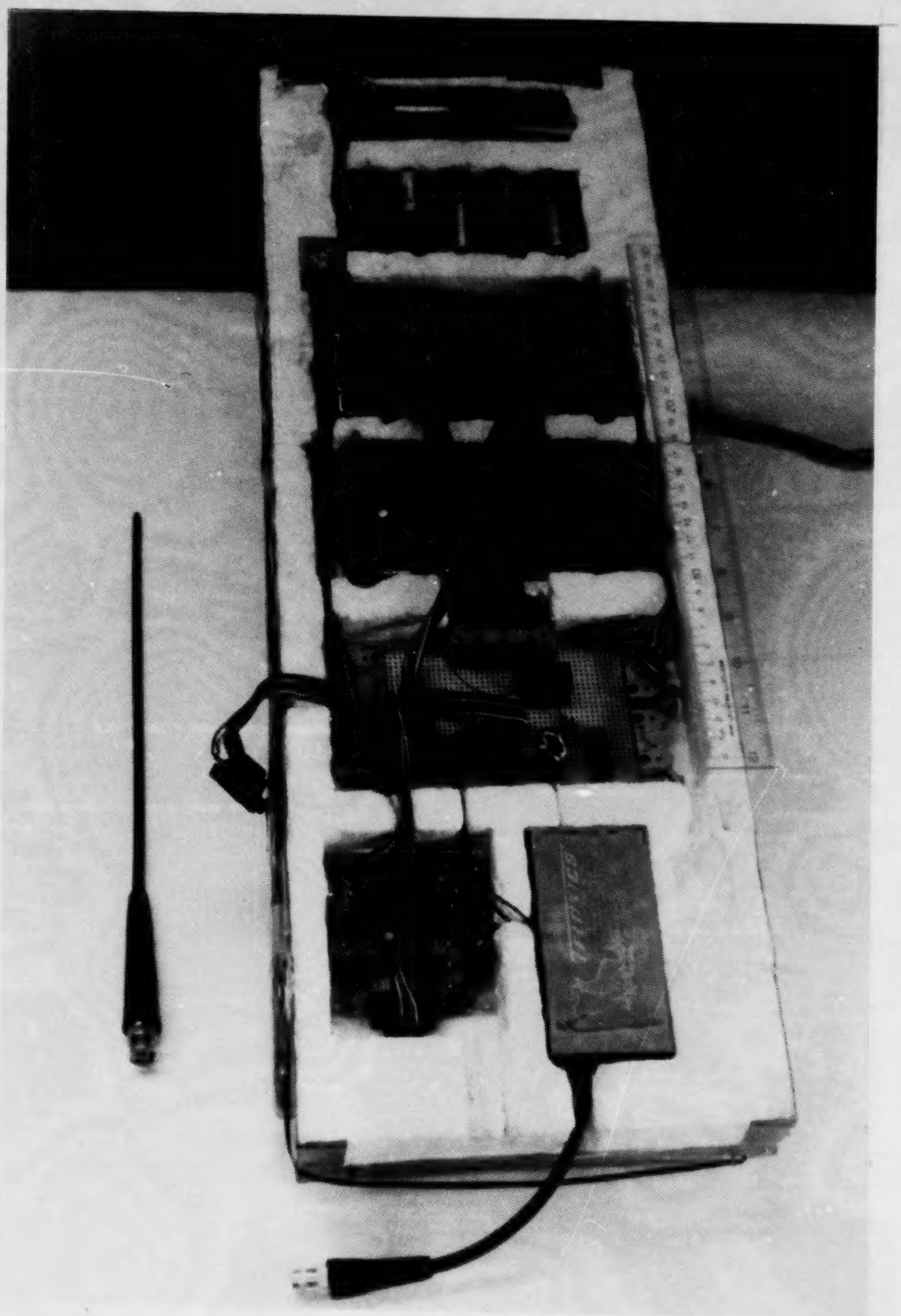

Figure 3-7. Main Electronics Package.

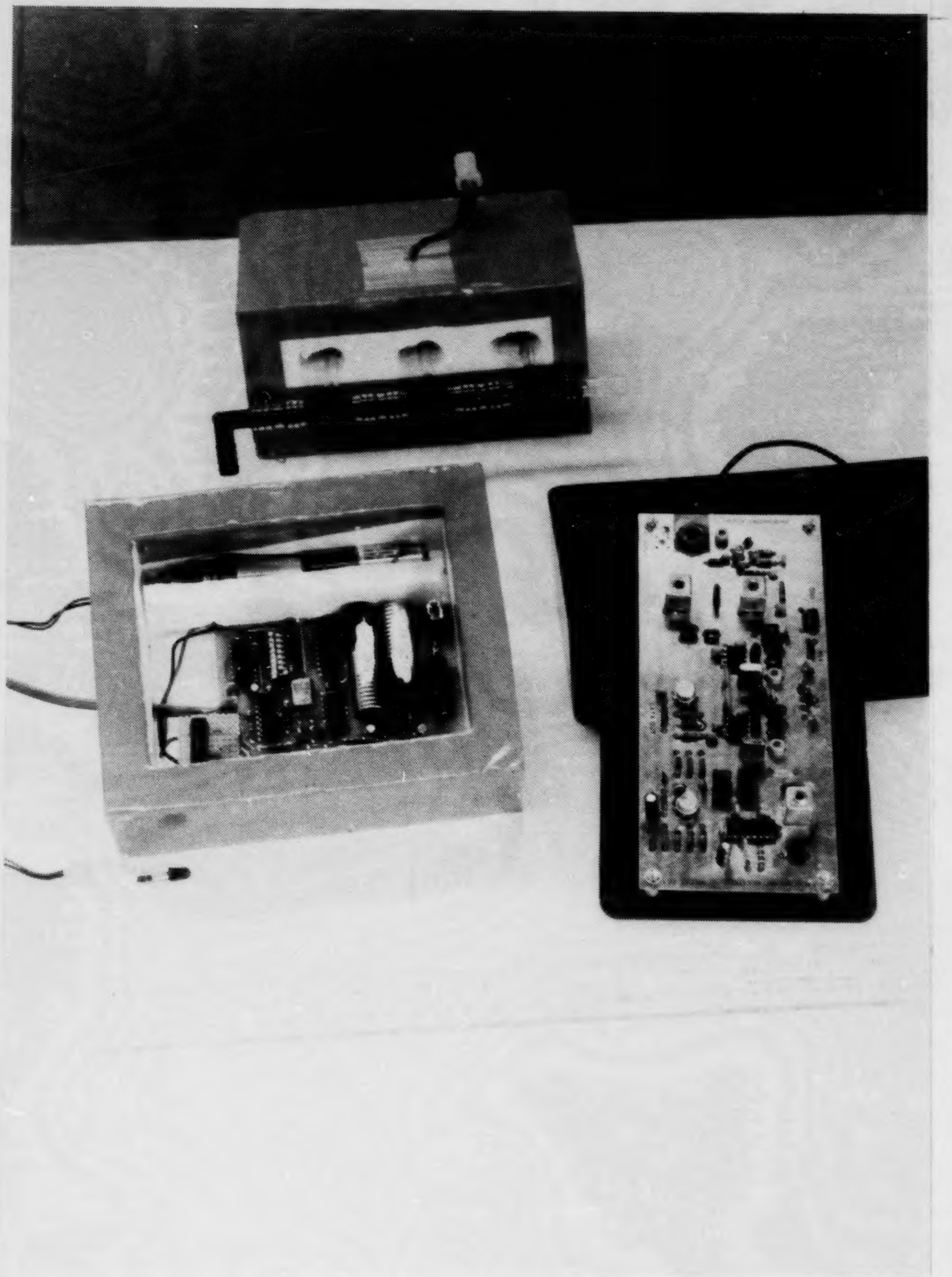

Figure 3-8. Timer Cutdown, Pump Box and Command Receiver.

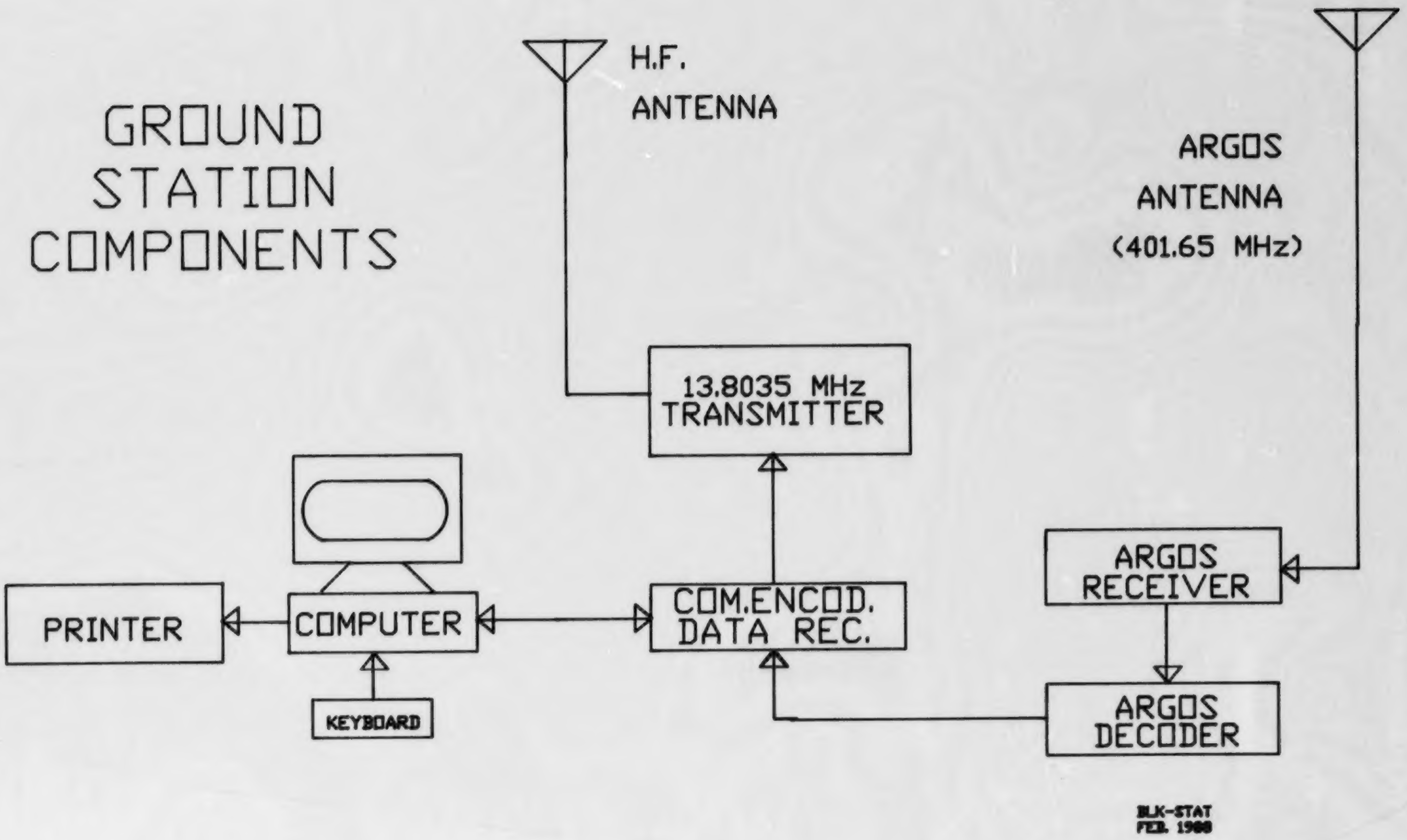
GROUND STATION COMPONENTS
H.F. ANTENNA
ARGOS ANTENNA (401.65 MHz)
13.8035 MHz TRANSMITTER
ARGOS RECEIVER
ARGOS DECODER
COM.ENCOD. DATA REC.
COMPUTER
PRINTER
KEYBOARD
BLK-STAT FEB. 1988

Figure 3-9. Command and Data Reception System.

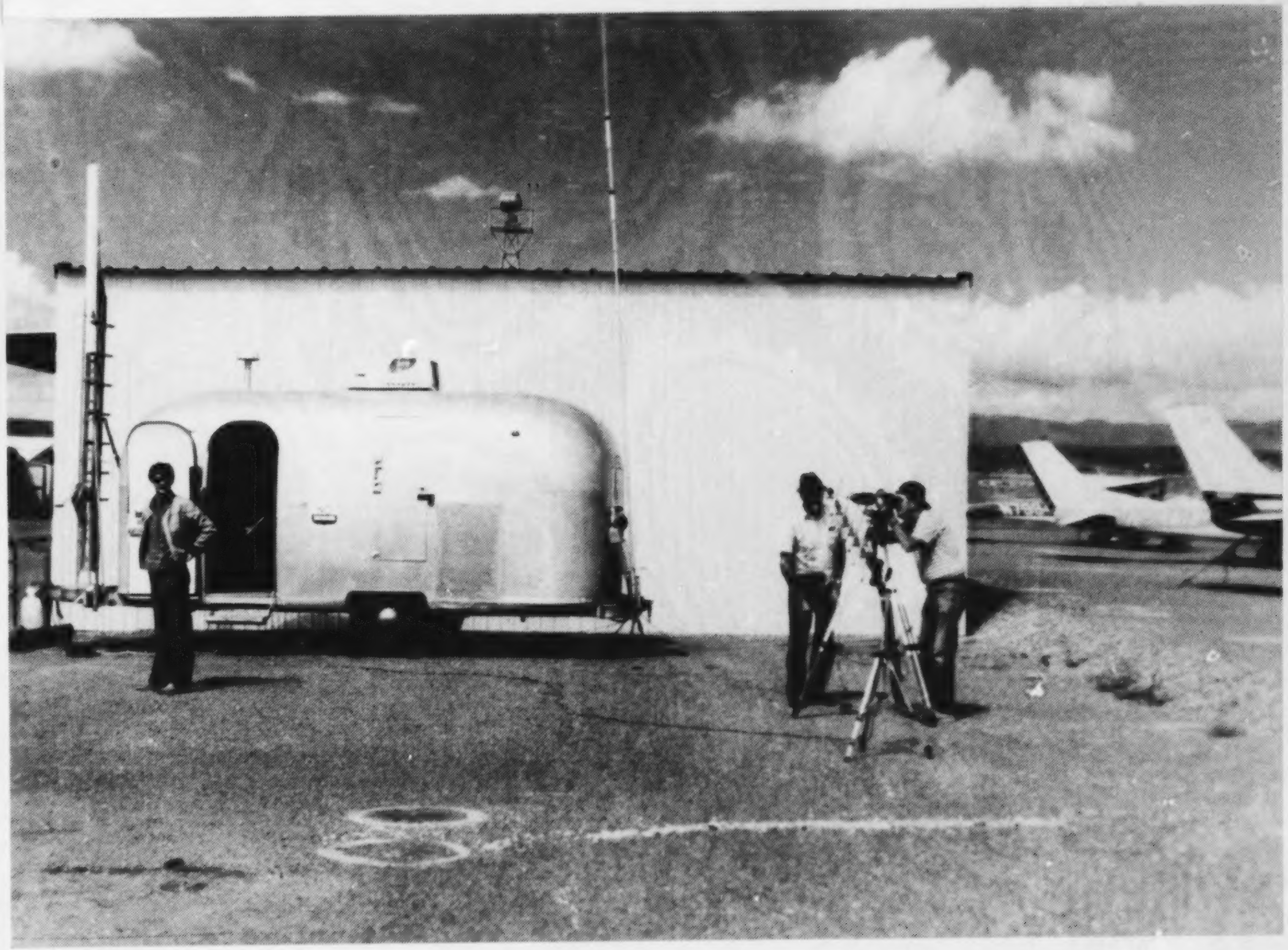

Figure 3-10. Ground Station for Flight 1.

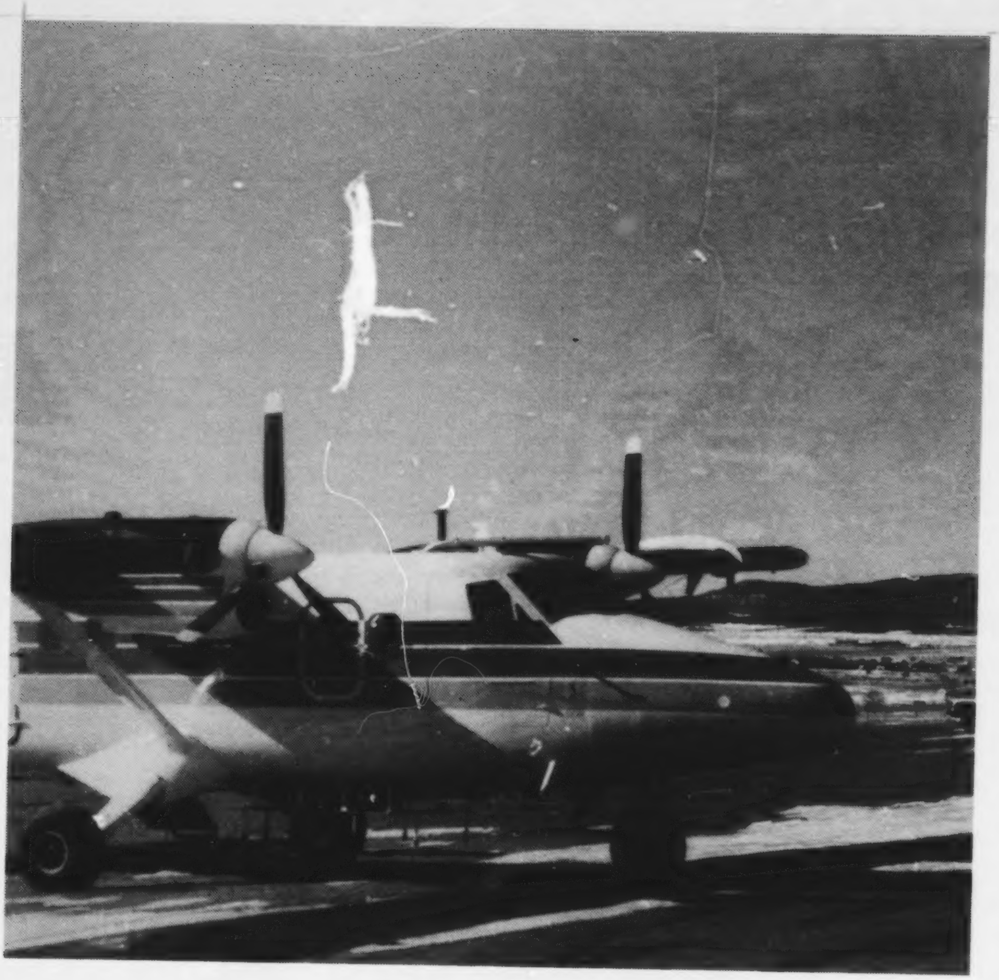

Figure 3-11. Chase Aircraft for Flight 2.

the Sandia de Haviland Twin Otter instrumented aircraft (Figure 3-11). The second flight was planned to be much longer. The PC converts the Argos data stream from hexadecimal to decimal form, formats it, and prints it out. It also archives the data on its internal hard disk. A vertical command antenna and the NCAR Argos antenna were used on flight one. On the Otter, the command antenna was a modified folded dipole mounted on eight inch insulating standoffs from an aluminum plate attached to the underside of the aircraft. The Argos signals could either be received on an omnidirectional antenna mounted on the left wing, or on a 6 element Yagi mounted from the "belly plate." The Yagi with its directional characteristics aids in finding the Tracer again if the aircraft has left its vicinity.

d. Inflation Shelter

Inflation of the Tracer Balloon in the field without suitable shelter would be very difficult. Consequently, for Phase II, a modular inflation and launch shelter was designed and built. For Phase III, a conventional hangar at a conveniently-located airport was used instead. More will be said about the tradeoffs and the optimum solution to the problem in the section on future work.

4. Flight Tests

The Phase II free flight tests had been conducted in a large open area (900 km^2) some 60 km south of Albuquerque. The Phase III flight tests, however, involved the transition to longer flights than could be accommodated within the Phase II test area. Consequently, the launch site was moved to a more appropriate location for long flights, Sandia Air Park, a small airport about 40 km east of Albuquerque near the community of Edgewood. This airport, just recently opened, had suitable hangar space available making it unnecessary to erect an inflation shelter. This launch site is located east of the Sandia and Manzano Mountains, so flights made under the influence of the usual westerly winds do not immediately encounter rough terrain from which Tracer recovery might be difficult, nor do they have to contend with heavy Albuquerque air traffic.

The balloon with serial number S/N 106 was moved to the airport at Edgewood the first week of August where it was inflated and monitored. Balloon superpressure was monitored using a manometer constructed from tygon tubing, a meter stick, and a backing board. The working fluid was ethylene glycol. The ambient conditions were determined with an aneroid barometer made by Wallace and Tiernan and the precision thermometer which is part of a mechanically aspirated psychrometer. Appendix A contains an expression relating observed superpressure to original superpressure given initial and final ambient temperature and pressure.

The outer balloon was found to leak badly. It was discovered that the circular seam at the top of the balloon connecting the gore structure with the central mylar piece had partially failed, leaving a slit through which one could insert one's hand! Because of the design, however, the gore structure and the mylar piece remained pressed together by pressure from the ballonet inside, forming a partial seal.

The balloon was depressurized, a patch put in place, and the area painted over with silicone sealer. Twenty four hours later the balloon was repressurized. Subsequent behavior of the balloon superpressure revealed no significant leaks.

The balloon was prepared for launch using the procedure outlined below. In order to carry out this procedure, one must know the weight budget. For the August flight the weight budget was:

o	Balloon Envelope (w/baseplate, attached valves, top fitting, fill line, and attached pendants)	5053 g
o	Payload	
	-Exterior sensor package	170
	-Vertical anemometer	143
	-Pump box (3 pumps)	534
	-Main electronics package	1347
	-Command receiver	309
	-Cutdown package w/cutdown timer	437
	-Argos antenna	117
	-Radar corner reflector	204
	-Telonics recovery beacon	68
	Payload Subtotal	3329 g
	System Total	8382 g

In weighing off the Tracer balloon system for launch, the formula for the required lift L_R is used (Appendix A). Note that the expression for L_R applies to a slack balloon (zero superpressure). Note also that if the balloon has been inflated for some time prior to weighoff, it is necessary to flush the air out of the outer balloon before adjusting the amount of helium in the ballonet to give the required lift. This is the case because helium diffuses slowly through the ballonet and accumulates in the outer balloon. After a few days, there is a significant concentration of helium in the outer balloon. If this condition exists during flight, each time air is released through the valve, helium will also be lost. Then when the pumps are activated to restore the original condition, it will take less air to bring the density of the system as a whole up to its original value. Hence, the superpressure will be lower, and the operational temperature range of the Tracer balloon system will be reduced. It has been found that a "Shop Vac" works very well for evacuating and refilling the outer balloon.

Once the amount of helium in the ballonet is adjusted to give the required lift L_R, then when the outer balloon is filled with air to the desired superpressure and the payload attached, the system will be approximately neutrally buoyant at the temperature and superpressure used in the formula for L_R. Fine tuning can be done by adding or venting relatively small amounts of helium and/or air. Note that the desired superpressure is chosen on the basis of the expected temperature range during the flight. At a fixed altitude, each degree Celsius change in balloon skin temperature will change the superpressure by about 3 mb (Appendix A). One needs to plan so that over the expected range of temperature during the flight, the superpressure neither declines to zero (in which case altitude control is lost), nor exceeds about 90 mb (beyond which the mylar balloon skin exhibits significant inelastic flow).

If it is desired to launch with some positive buoyancy, say 200 g, then the ballonet should be inflated to give gross lift of L_R + 200 g. For the first generation balloon, assuming a standard atmosphere, each gram of free lift corresponds to about 1 m of elevation of the equilibrium altitude above the surface (Appendix A). If launch is delayed so that the ambient temperature changes significantly between weighoff and launch, it may be desirable to adjust the air ballast accordingly to give the proper buoyancy at launch. This adjustment can be accomplished without further weighoff by metering air in or out of the balloon through an integrating flow meter such as a dry gas meter.

The procedures used for launch preparation and checkout on the day of the flight are covered in Appendix F. The Tracer Balloon was brought out of the hangar shortly after 9 am (Figure 4-1). Liftoff of Phase III flight 1 occurred at 10:49 am on August 13, after the launch crew had overcome the problems created by the spurious cutdown system firing mentioned earlier. Those problems delayed launch until after the morning surface inversion had burned off. Winds at the surface at launch time were estimated to be gusting to 15 kts. Nevertheless, the launch was successfully executed (Figure 4-2).

Because of the high winds and the Argos antenna problem referred to earlier, the Tracer Balloon was carried out of range of the Argos ground-based data reception system quite rapidly. However, data from the AIR sonde attached to the skin of the balloon continued to be received through most of the flight. The AIR airsonde was manually tracked with a 6 element Yagi. The Tracer Balloon was also observed visually to respond to radio commands after Argos data was lost. In the absence of Argos data, however, it was decided that it would be best to allow the cutdown timer to terminate the flight at one hour.

Shortly after launch, the ground chase crew left the launch site to follow along with the balloon on back roads to be nearby

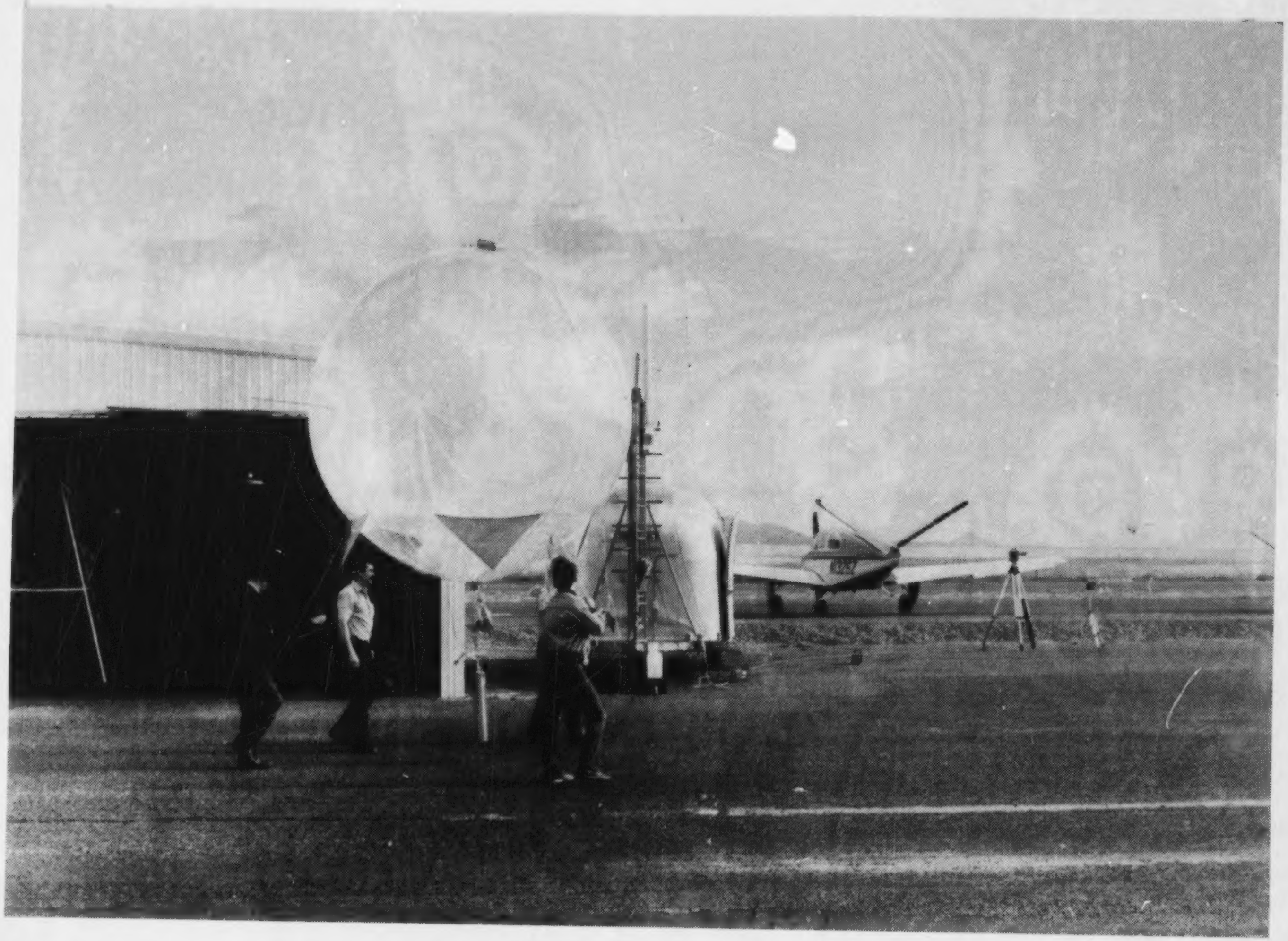

Figure 4-1. Moving the Tracer into Position for Launch.

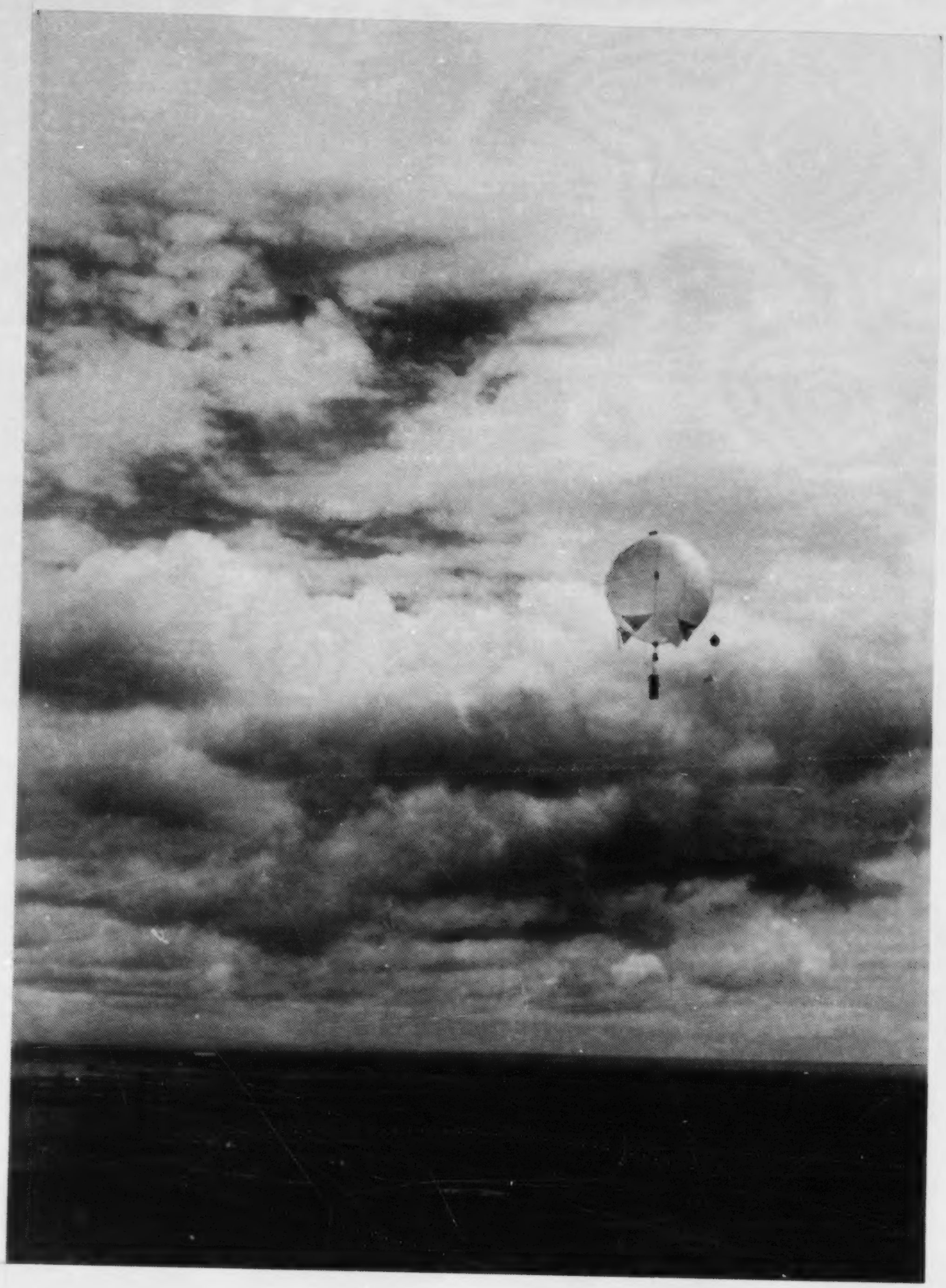

Figure 4-2. Tracer Embarking on Flight 1.

when the balloon was brought down. However, a section of flooded road made backtracking necessary during which visual contact with the Tracer was lost. Nevertheless, the optical theodolite data gave the chase crew a fair idea where to look for the Tracer balloon after it had been brought down. It was found about an hour after cutdown, with most of the helium still inside, snared on a barbed wire fence about 14 km from the launch site (Figure 4-3). As expected, the payload was undamaged, but the combination of high winds and barbed wire had damaged the outer balloon envelope beyond repair.

Note that the vertical profile of the flight is given in Figure 4-4, and the horizontal trajectory in Figure 4-5. The AIR data is tabulated in Appendix G.

The second Phase III test flight was delayed by the commencement of a previously-scheduled field program in another project, and by the modifications which were felt to be necessary on the basis of the results from flight 1. Preparations for the second flight began in December, and the flight itself took place in January.

This second flight was to be a longer flight at higher altitude -- initially of order 1000 m above ground level. Hence, the Terra FAA transponder with encoding altimeter was required in order to comply with the agreement worked out with the FAA Albuquerque Air Route Traffic Control Center (AARTCC).

The transponder together with the encoding altimeter and batteries packaged in styrofoam weighed 1.8 kg. That made for a total payload of about 5.15 kg (11.3 lbs), and a total system weight including the balloon of 10.2 kg. The expression for L_R and the ceiling altitude z_m were evaluated to see if the first

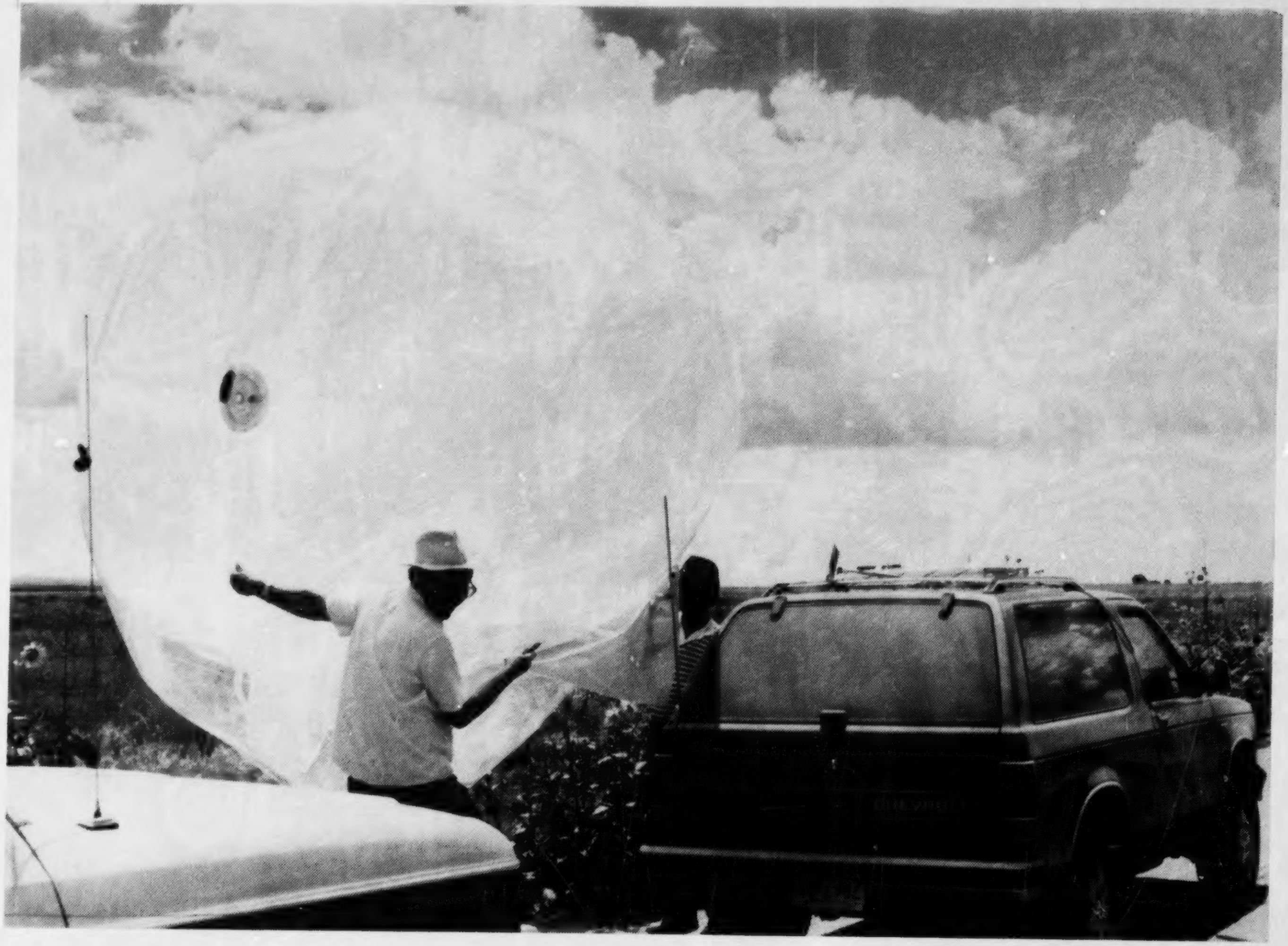

Figure 4-3. Recovery of Tracer from Flight 1. The recovery was complicated by high winds and a barbed wire fence.

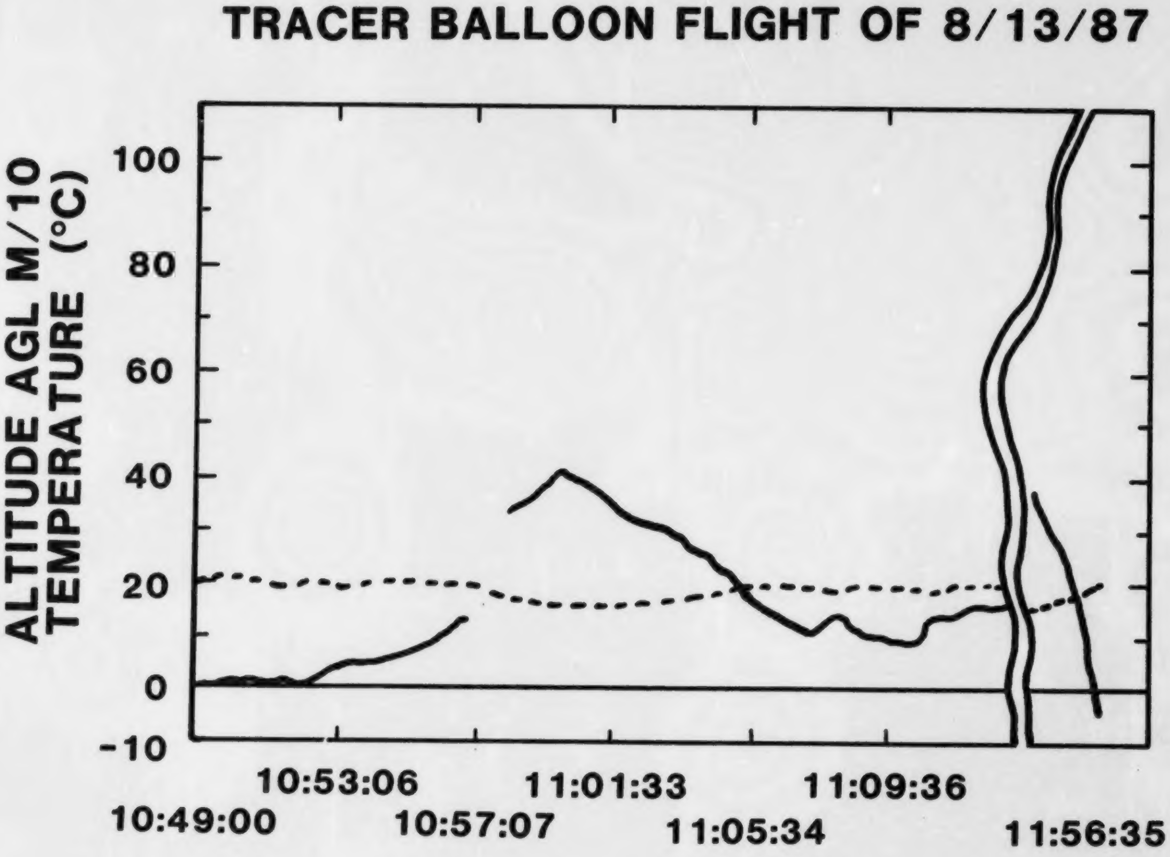

Figure 4-4. Vertical Profile of Flight 1. Solid line is altitude in metres/10; dashed line is temperature.

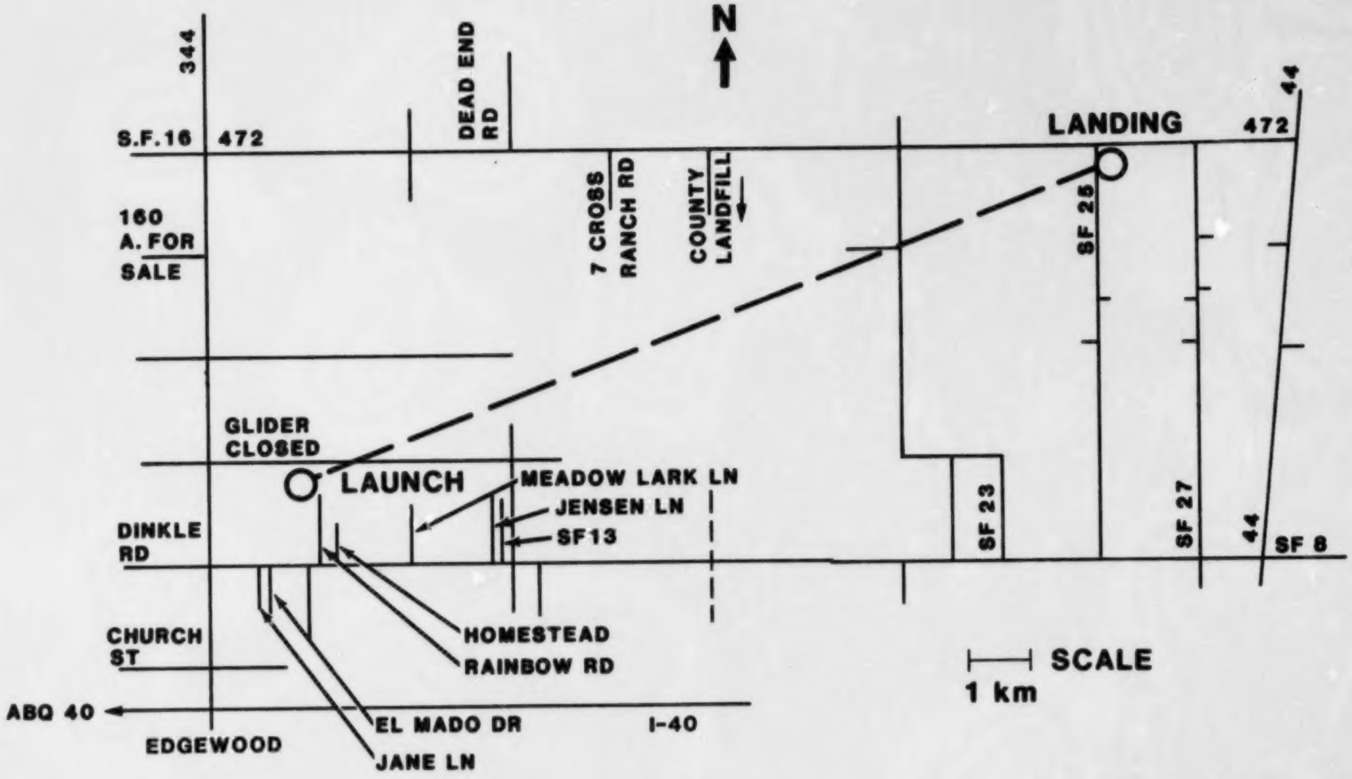
N
344
S.F.16
472
DEAD END RD
7 CROSS RANCH RD
COUNTY LANDFILL
LANDING
472
44
160 A. FOR SALE
SF 25
GLIDER CLOSED
LAUNCH
MEADOW LARK LN
JENSEN LN
SF13
SF 23
SF 27
44
SF 8
DINKLE RD
CHURCH ST
HOMESTEAD
RAINBOW RD
SCALE
1 km
ABQ 40
EDGEWOOD
EL MADO DR
I-40
JANE LN

Figure 4-5. Horizontal Trajectory of Flight 1.

generation balloon could handle the addition of the transponder. Assuming an initial superpressure of 40 mb, and an initial temperature of 0 C, we found a gross required lift of about 10.8 kg and a ceiling altitude of 2120 m MSL (6959 ft MSL). This ceiling altitude is only a few hundred feet above the surface at Edgewood, and lower than the height of downwind ridges. Hence, to fly the transponder required additional lift beyond that available from the first generation adjustable buoyancy balloon. As mentioned in an earlier report, the first generation balloon as delivered weighed somewhat more than expected, and the balloon volume was less than specified (Zak et al, 1987).

The solution chosen was to balance the weight of the transponder with a zero pressure balloon attached to the top of the adjustable buoyancy balloon. In that way, if one ignores thermal effects (heating of the balloon above ambient temperature by solar radiation), the weight of the transponder remains balanced by the lift of the zero pressure balloon independent of altitude. Consequently, in doing required lift and ceiling altitude calculations for the tandem balloon system, one may ignore the weight of the transponder and the presence of the auxiliary balloon. Under these circumstances, the effective system mass becomes 8.4 kg; the effective required gross lift is about 9 kg; and the ceiling altitude is about 3990 m MSL (13,100 ft MSL). These figures were quite adequate for our plans. The auxiliary balloon used was a Raven 6 m^3 tetroon which happened to be on hand from a previous project (Figure 4-6).

On January 13, the Tracer balloon was brought out of the hangar and moved to the launch area around 10:20 am. The Tracer balloon payload had already been checked out in the hanger, but nonetheless, final checkout revealed connector problems -- the insulation displacement connectors used seemed to be

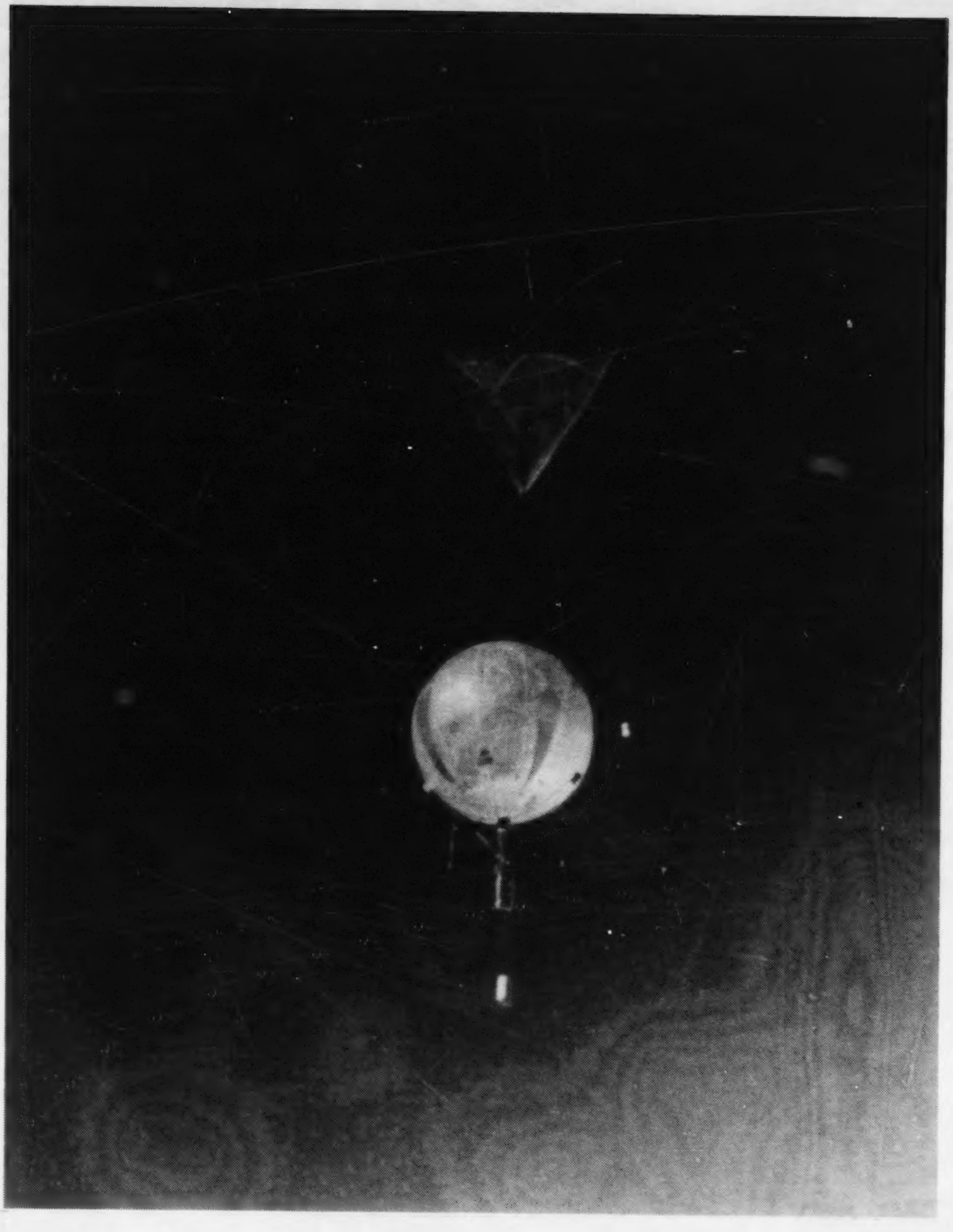

Figure 4-6. Tracer Embarking on Flight 2. Note the addition of the FAA transponder package below, and the auxiliary balloon above.

particularly unreliable in cold weather. Finding and correcting these problems delayed attachment of the auxiliary balloon and subsequent launch. Launch took place at 1:29 pm.

During the delay, the air temperature had risen several degrees. Although provision had been made at weighoff for 200 g of free lift, the Tracer balloon was essentially neutrally buoyant at launch. A valve command was sent, and slowly the Tracer Balloon began to rise.

About 12 minutes into the flight, the balloon had risen to about 110 m above ground level. At that level, the Tracer encountered an intense wind shear layer. Below that level, the winds were light and from the southeast. Above that level winds were much stronger and directly out of the west. The shear was so violent that the rigging holding the main electronics package and the transponder to the main balloon failed. As specified in FAR 101, the rigging was designed and confirmed by test to fail at a tension of less than 50 pounds. It is speculated that perhaps the coupled oscillations induced by the shear in the complicated tandem balloon system may have been responsible for whiplash of the payload packages with high resulting g forces. In any case, at a height of approximately 110 m at a distance of about 1.5 km from the launch point, the main electronics and the transponder packages fell to earth. The tandem balloon system, released from much of its burden, began to rise rapidly. At this point the chase aircraft took off to keep near the balloon system, and to keep the FAA informed as to its location. Without the transponder, the FAA radars were reduced to tracking the radar corner reflector, but as the distance from the FAA radar increased, they eventually lost the ability to track that return.

With the loss of the main electronics payload, automated control, remote command capability and the Argos data link were also lost. The AIR sonde velcroed to the balloon skin, however, continued to send data. The main and auxiliary balloons remained together and rose to a maximum altitude of about 5200 m (17,100 ft MSL), and then came slowly back down. The aircraft caught up with the balloons as they passed through 3800 m on the way down. At that point there was no visual evidence that either balloon envelope had suffered catastrophic failure. Rather it appears that the thin membrane which is part of the cutdown device on the main balloon served as a pressure relief device and blew out when the superpressure exceeded the strength of the membrane or the membrane holder. The cutdown device would not have fired before the balloon began descending.

The chase aircraft followed the tandem balloon system until it touched down about 16 km west of the village of Anton Chico, about 83 km from the launch site. The vertical profile of the flight is given in Figure 4-7, and the horizontal trajectory in Figure 4-8. The tabulated data is given in Appendix G.

The AIR data clearly recorded the loss of the payload at the wind shear. The theodolite data enabled the event to be localized. Two days after the flight, we recovered the main electronics and the transponder packages within one to two hundred metres of the calculated point of loss. Surprisingly, the damage to both was minor. They had fallen into a patch of snow.

Radio navigational data had been recorded onboard the chase aircraft at the point of the balloon envelope touchdown. The landing point is estimated to have been established to within ±2 km both north-south and east-west. Thus the landing point is

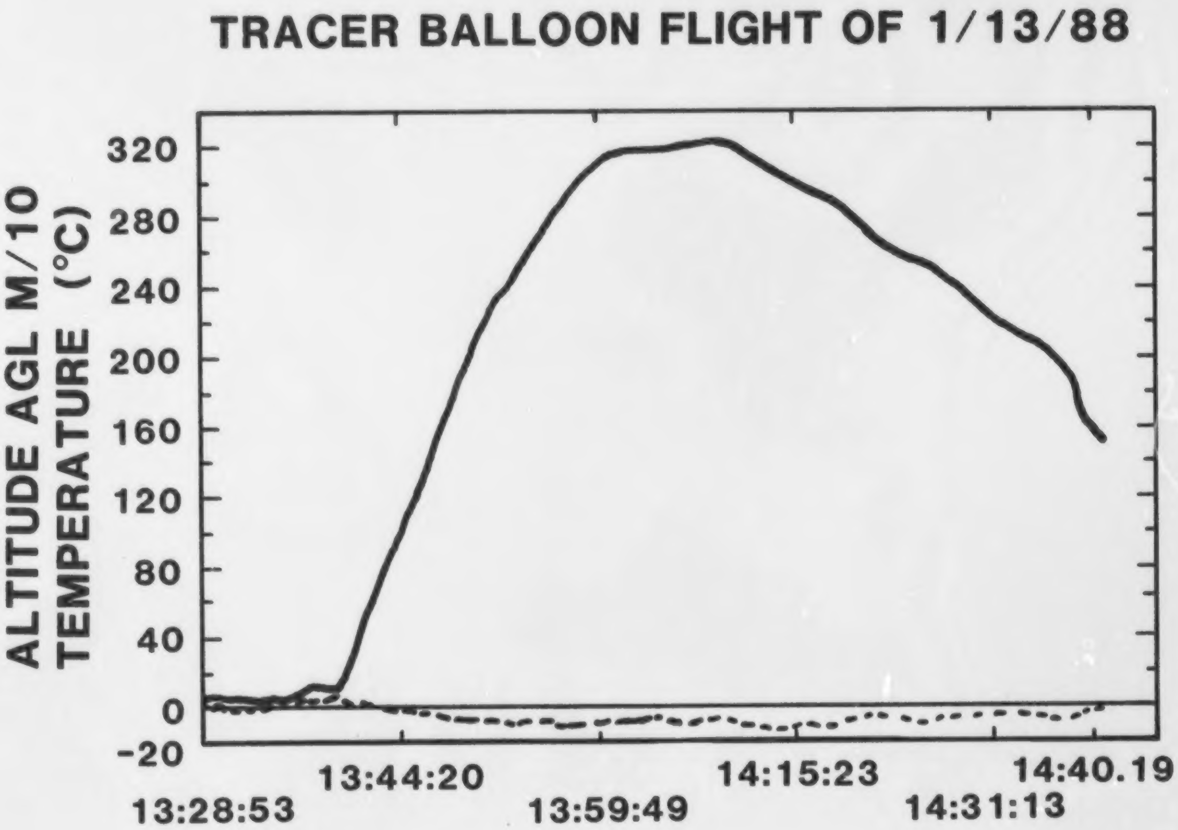

Figure 4-7. Vertical Profile of Flight 2. Solid line is altitude in metres/10; dashed line is temperature.

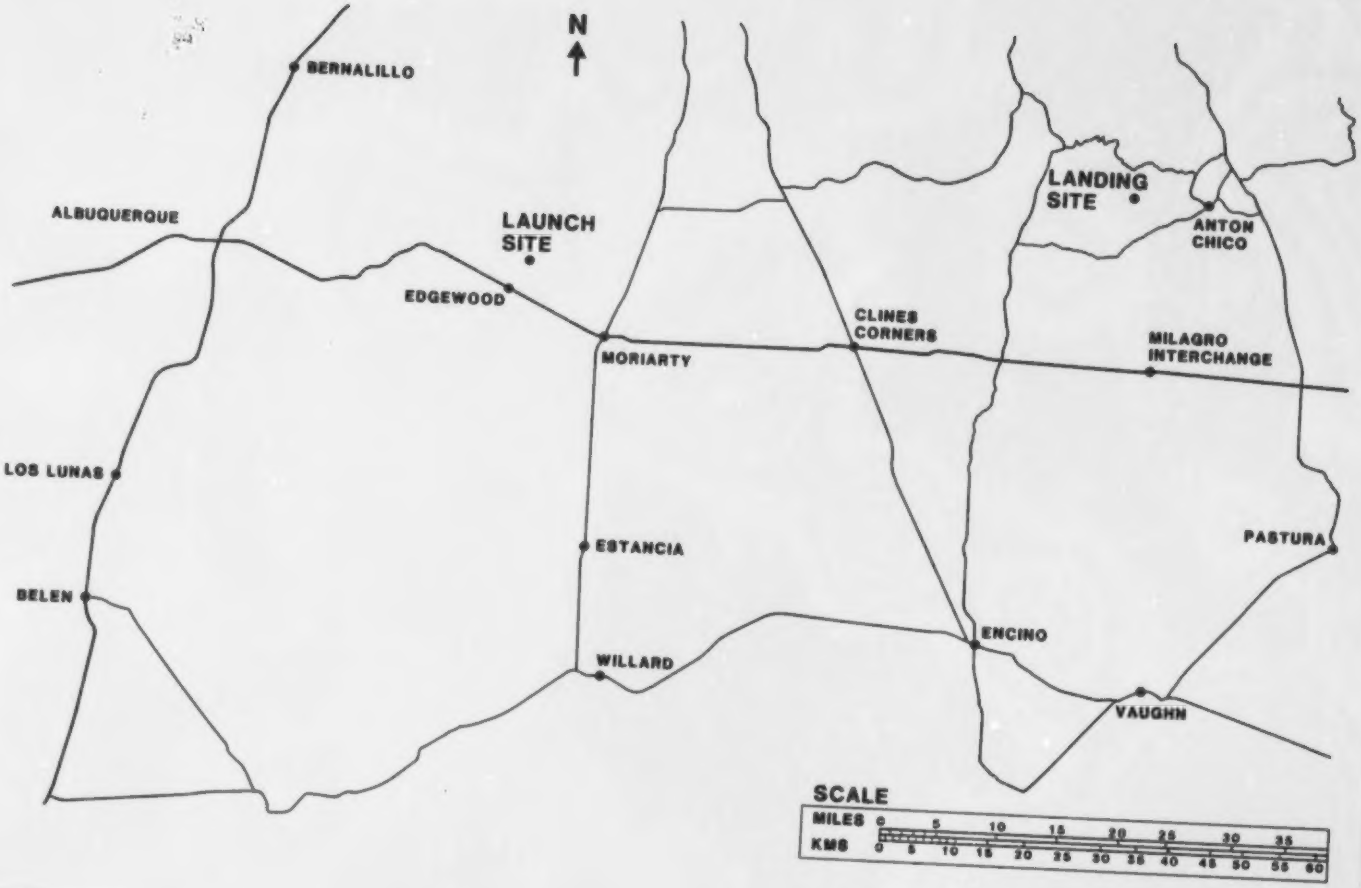
N
BERNALILLO
ALBUQUERQUE
LAUNCH SITE
EDGEWOOD
MORIARTY
CLINES CORNERS
LANDING SITE
ANTON CHICO
MILAGRO INTERCHANGE
LOS LUNAS
ESTANCIA
BELEN
PASTURA
ENCINO
WILLARD
VAUGHN
SCALE
MILES 0 5 10 15 20 25 30 35
KMS 0 5 10 15 20 25 30 35 40 45 50 55 60

Figure 4-8. Horizontal Trajectory of Flight 2.

believed to have been within a well-defined 16 km^2 area. The weekend following the flight, an attempt was made to locate the balloons in this area. The attempt was not successful. The landing point was in hilly terrain covered with scrub pinyon and juniper. The area is serviced only by dirt roads. It is ten km or more to the nearest secondary paved road. Snow which had fallen some weeks before was now melting, making the dirt roads impassible in places. By 4 WD vehicle, a ground search crew got to within about 5 km of the spot indicated by the radio navigational information, and hiked in the remainder of the way. An aircraft aloft with a radio link to the ground crew systematically searched the area for nearly 3 hours, but failed to locate the balloon. The search was complicated by the fact that from a few hundred feet, a collapsed balloon probably looks much like a patch of snow -- of which there were thousands in the area. After the search was abandoned, a sign promising a reward for the balloons was posted in the general store at Anton Chico.

While the recovery of the main electronics and transponder packages yielded the larger benefit, nevertheless, it would have been worthwhile to recover the balloon envelope, even if as expected, it were not repairable. The greatest benefit would have been to be able to examine the balloon to determine with certainty how the balloon actually vented, although recovery of the balloon fixtures and incidental packages attached to its skin would have been welcome as well.

At this point in the effort, the resources available to pursue the test flights were exhausted, and the deadline for the draft Phase III report was fast approaching. Hence, the Phase III test program was brought to a close.

5. Future Work

a. Further Improvements

Although most of the improvements called for in the Phase II report have now been made, it is clear from the Phase III results that several more are in fact necessary. It is apparent that Phase IV of the project as originally planned would be highly beneficial to complete the development of the Adjustable Buoyancy Tracer Balloon.

We start with the adjustable buoyancy balloon envelope itself. Most importantly, the balloons as obtained from the manufacturer must be reliable. The balloons must be so constructed that on delivery, they are leak free and ready for use. Problems with damage to the inner ballonet on installation in the outer balloon during the manufacturing process need to be overcome; leaks at the top and bottom fixtures need to be eliminated by improved design; and failure of the circular top seam joining the gore structure to the top mylar piece must be eliminated by proper reinforcement at the factory. In view of the innovative nature of this balloon design and fabrication task, it is not surprising that these problems were encountered. Nevertheless, these problems must be eliminated if the technology is to see routine use.

In addition, most of the changes and additions spelled out in the original design of the second generation balloon should be implemented, including: a drip skirt below the equator of the balloon to shed condensation or rain, and to prevent its accumulation at the bottom of the balloon; a water repellant coating to minimize the burden of water which can accumulate on the balloon; stronger load patches; a ballonet made of a material which is less permeable to helium than polyethylene, perhaps polyurethane (permeability of 1 mil thick film, about 3.8 litres per sq metre per 24 hours, about half that of polyethylene); and a volume of about 15 instead of 12 m^3, so that no auxiliary balloon is necessary.

Clearly the rigging of the payload needs to be improved as well to assure that it is not possible to lose the payload in turbulence or wind shear. It is noted that the packages velcroed to the skin of the balloon appear to have survived without difficulty. Attaching all of the packages in this way may be the solution. This attachment method is such that it takes less than a 50 lb force to separate each package from the balloon, so the requirements of FAR 101 are met; yet with this method of attachment, it is difficult to conceive how large g forces could be generated. In the absence of an extended line between the balloon and the package, whiplash action is not possible.

The top fitting and the associated cutdown device also need redesign. The fabrication of the fitting as it currently exists requires extensive machining, is prone to leak, and makes installation of the electric matches difficult. The current plan is to separate the top fitting from the cutdown device. In the proposed design, the top fitting is a simple cap modified to accept a right angle push-on fitting for surgical tubing. The cutdown device is a separate piece consisting of the spectroscopic sample cell modified to accept push-on surgical tubing on each side. There would be two membranes, one on each side of the sample cell, with an electric match facing each one (Figure 5-1).

While the Gilian pumps appear to be quite satisfactory (provided one procures the correct model), the Klippard valves

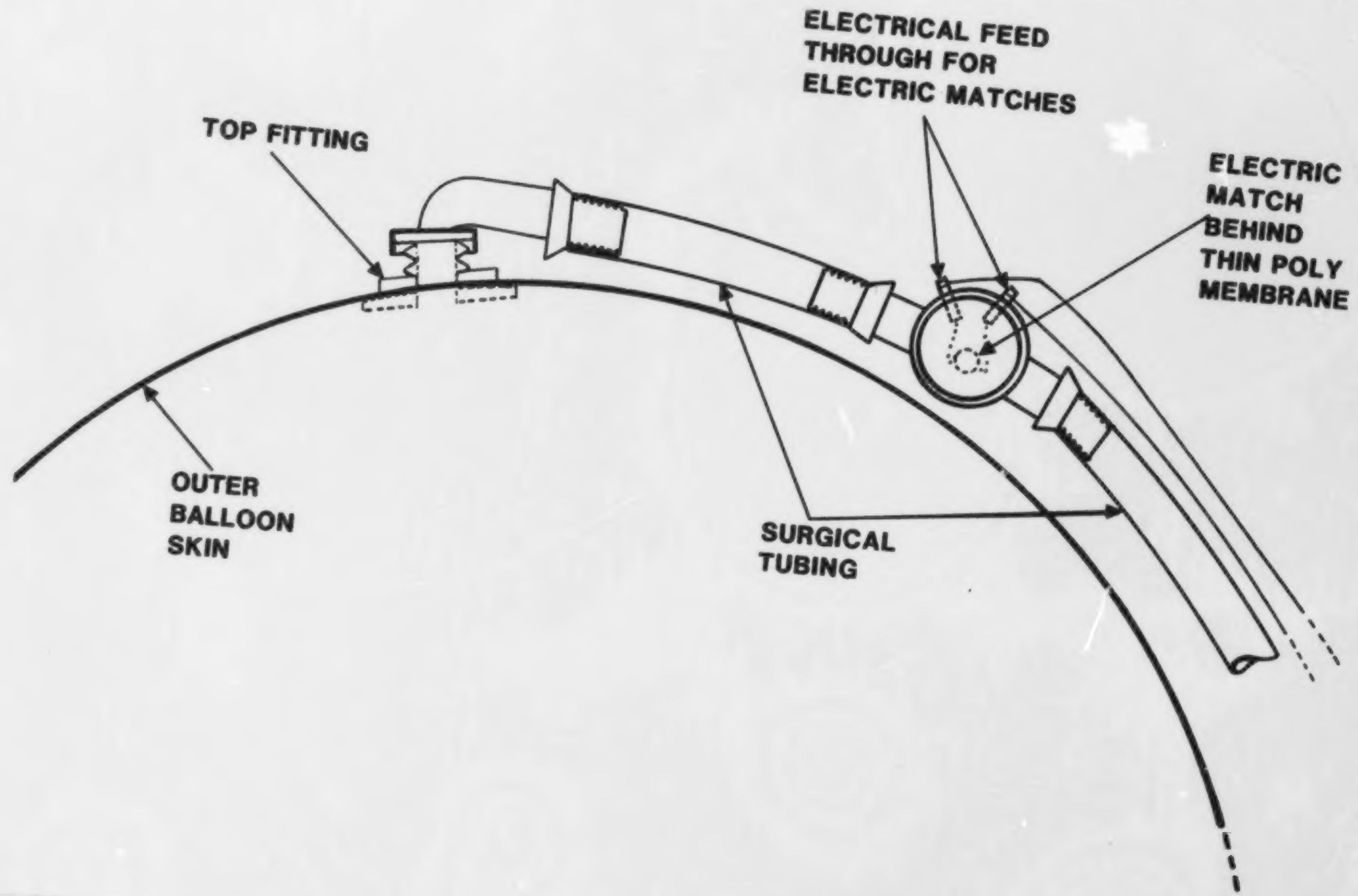
ELECTRICAL FEED THROUGH FOR ELECTRIC MATCHES
TOP FITTING
ELECTRIC MATCH BEHIND THIN POLY MEMBRANE
OUTER BALLOON SKIN
SURGICAL TUBING

Figure 5-1. Redesigned Top Fitting and Cutdown Device.

leave something to be desired. They are made of brass, and have a low conductance. Brass is heavier than necessary, and the low conductance limits the speed with which the Tracer Balloon can change its equilibrium density altitude in response to vertical air motion. It is probably possible to find similar valves in either plastic or aluminum, and which have higher conductance.

Finally, the pendants which are attached to the balloon to improve visibility still leave something to be desired. In Phase III, an orange translucent material used to cover model aircraft (econokote) was used. It seems likely that the material from which vividly-colored surveyors' tape is made would be more visible. This material is available from the manufacturer in suitable dimensions.

With regard to the electronics, the biggest problem encountered in Phase III was with the insulation displacement connectors. In a cold environment, connections which were made and unmade frequently proved to be unreliable. These connectors have since been replaced.

In Phase III, a USART was installed to service the AIR sensor assemblies. Currently, the USART is tacked into place in a temporary fashion. The board on which it is mounted should be redesigned to properly accommodate the USART. In addition, the machine language software should be modified so that standard, rather than special order AIR sensor assemblies can be used. Now that the USART and machine code subroutine are in place, there is no advantage to retaining the original data format rather than the current format used by AIR. The standard units are much cheaper.

The control software still does not contain provision for either an effective potential temperature control algorithm to function in an environment which contains liquid water, or provision for self-selection of control algorithm. Both should be implemented.

As noted in an earlier section, questions have arisen about the shelf life and low temperature performance of the brand of lithium batteries used in Phases II and III. Additional work should be done to clear up these questions, and, if necessary, to change to a different type of lithium battery.

The command and data reception system currently makes use of a Handar Argos receiver and decoder. It is obsolete, and in a cold environment, does not function properly. It should be replaced. Telonics makes a suitable unit with the same function. In addition, a second command and data reception system should be built. For long Tracer Balloon flights, use of an aircraft will prove to be very convenient -- provided that one has a command and data reception system on the aircraft as well as on the ground. This redundancy also provides important backup capability.

Finally, there is the question of provision of a portable inflation shelter. The inflation shelter used in Phase II proved to be cumbersome at best. It was of marginally adequate size for a first generation balloon, but would not be big enough for a second generation balloon. In contrast, the use of the hangar in Phase III worked out quite well. The problem, however, is that a suitable hangar or high bay area may not be available at all future launch sites. This problem can be ammeliorated by constructing a trailer for transporting the inflated and weighed off balloon from a building with a high bay area for inflation and weighoff to the planned launch site. As remarked earlier, as long as the ambient temperature and pressure is recorded at weighoff, and is also measured at the launch site, the buoyancy of the system can be appropriately adjusted using an integrating flow meter. This approach seems preferable to attempting to construct a suitable portable inflation shelter at the launch site.

b. Shorter Flight Version

It has come to our attention that many potential applications for an adjustable buoyancy Tracer Balloon do not require the stringent design goals specified for this development effort. In particular, systems capable of making much shorter flights than 72 hours would be useful in many situations. If the 72 hour requirement is dropped, and if one focuses on lower altitude applications which do not require an FAA transponder, it would be possible to build a Tracer Balloon that is smaller, much more convenient to use, and which costs considerably less. As a follow-on to the development of the Tracer Balloon meeting the original EPA design goals, a promising direction would be to develop a scaled down version for shorter duration experiments. The major design changes this permits are fairly obvious: lighter battery complement, a short range tracking system, a smaller balloon, fewer pumps, etc.

c. Required Tests

The goal of the test program is to check each significant aspect of the performance of the Tracer Balloon system. While resources do limit how thorough a test program can be mounted, it is nevertheless important to keep the goal in mind. From our present perspective, the most important required tests remaining are environmental chamber tests to investigate the low temperature long term (72 hour) behavior of the payload as a whole and the lithium batteries in particular, and free flight tests. The free flight tests should demonstrate the proper function of the system for an extended period of time, preferably in excess of 12 hours. If possible, they should also demonstrate the high altitude (hence, low temperature) performance of the system in the real atmosphere. Beyond these efforts, further "testing" is likely to take the form of actual use of the Tracer system for specific applications involving various meteorological conditions. Testing for the purpose of exploring and extending the limits of the technology is unlikely to attract financial support.

5. Discussion and Conclusions

The stated design goals for the Adjustable Buoyancy Balloon Tracer form a useful frame of reference for evaluating the status of the effort.

- Operates under the exemption clauses of FAR 101.

FAR 101 permits up to 12 lbs (5.45 kg) of payload, as long as the payload is distributed in packages weighing no more than 6 lbs (2.73 kg) each, which meet a 3 oz/in^2 (13.2 g/cm^2) areal density limit, and which are connected by a "rope or other device for suspension" that requires a force of no more than 50 lbs to part. The weight of the Phase III modified operational prototype Tracer payload as flown with transponder and encoding altimeter was 5.15 kg, just under the 5.45 kg limit. The modified operational prototype payload met the other exemption conditions of FAR 101 as well. Inclusion of a strobe for night flying will require that careful attention be given to weight. There is good reason, however, to believe that a strobe based on the unit identified earlier could fit within the 12 pound payload weight limit.

- Lifetime $\geq$ 3 days

Available battery power determines the Tracer effective lifetime. The major power drain on the Tracer was the set of three Gilian pumps. At 45 mb superpressure, the pumps consume about 1 watt each. If one assumes that they would be on about 1/3 of the time, in a 72 hr flight, they would require 72 watt hours of energy. The power for the pumps is supplied by lithium batteries with an advertised energy density of 0.43 watt-hours/g (195 watt-hours/lb). Two D cells in series (to get the required voltage) should supply approximately 100 watt-hours of energy, more than enough for the pumps. The D cells weigh 117 g each.

The main electronics package including the sensors requires about 1.4 watts continuously. Over 72 hours, the need is for 100 watt-hours of energy. Again, 2 D cells should fulfill that need. The battery complement is completed by 3 C cells for the Argos PTT and 2 AA and 2 C cells for the cutdown device. Because of the low duty cycle, the Argos PTT has a low energy requirement. The cutdown device fires just once, independent of the length of flight. The C cells weigh 58 g, and the AA cells, 21 g each. Thus, for a 72 hour flight, the battery complement for the modified operational prototype weighs 800 g. What has been described is the battery complement as actually flown on the Phase III flights with the exception of the batteries required for the FAA transponder. Four D cells were flown with the transponder, providing about 200 watt-hours of energy. This should be adequate for at least a 40 hr flight. Thus far, the transponder has been flown with no power saving modifications. Minor modifications such as disabling panel lights are expected to enable the 4 D cells to keep the transponder going for the full 72 hours.

It is well to note, however, the caveat mentioned earlier that the two year old lithium batteries procured from Altus may not live up to their advertised capacity at low temperature. While there is no reason for pessimism, further work may show that care will need to be taken to assure that the batteries are fresh, and that the thermal design of the system keeps them from getting too cold. Alternately, lithium batteries from another supplier may prove superior.

- Tracking range $\geq$ 1000 km

Argos tracks world wide. In Phase III, for the first time, Argos satellite data from the balloon payload was obtained (Appendix E). It works! The data was obtained while the payload was on the ground inside the hangar rather than in flight. No satellite passes occurred during the flights.

- Telemetry of relative vertical air motion, pressure, temperature, and humidity.

The Argos PTT presently accommodates these variables and can accommodate several others if desired.

- Ground system capable of handling several Tracers at a time.

Argos can handle 200 PTTs in its field of view at a time. The existing command system can accommodate different codes to address each of several Tracers.

- Capable of establishing specified ascent and descent rates under radio command.

With appropriate additional commands implemented, the equilibrium altitude could be modified over a broad range of rates.

- Capable of reaching altitudes up to 5.5 km (500 mb).

With an appropriately-sized second generation balloon, the balloon should pose no problem. If any problem exists, it is likely to be the inability of some component to operate at the low temperatures encountered at that altitude (20-25 degrees below zero Celsius). The pumps and the batteries have been operated in a freezer at -18 C, but the entire payload still must be checked in an environmental chamber. Should some existing component fail the test, it is reasonable to assume that a substitute with better low temperature performance could be found. Typically military specifications require yet better low temperature performance.

- Capable of following mean vertical flows as low as 1 cm/s with "acceptable" fidelity.

An experimental test would involve comparison of the trajectory of the Tracer Balloon with that of a gaseous or fine particle tracer released in its vicinity. There is good reason to believe that this specification would be met based on the arguments presented in the Phase I report.

- Sufficiently inexpensive to permit use in significant numbers on an expendable basis.

This goal is inexact. We choose to address it as in Phases I and II by considering the likely cost of the elements of an operational Tracer procured in small numbers (<10), and in large (>50).

Cost Elements	Cost Each ($K)*	
	1-10	>50
CVB with Ballonet	2.0	1.5
Buoyancy Adjustment Subsystem	0.5	0.3
Sensors	0.6	0.4
Microcomputer	0.1	0.1
Argos PTT	2.6	2.3
Command Receiver and Decoder	0.5	0.3
FAA Transponder and Strobe	1.0	0.8
Batteries	0.2	0.2
Miscellaneous Hardware	0.2	0.2
Assembly Labor	1.0	0.5
TOTALS	8.7	6.6

*CY88 Dollars

These cost estimates reflect actual experience in building the Phase II and III operational prototype Tracers as modified by subsequent cost increases for components. The costs in quantity are approximate, and merely project typical quantity procurement savings.

In field experiments to date, five flights have taken place. In four of those flights, the payload was recovered with no damage. In the fifth, damage was limited to a few hundred dollars. This suggests that if a payload recovery effort is mounted, the average cost of replacement hardware per use of the Tracer would not greatly exceed the cost of the balloon itself. Thus the cost of a field program using Tracer Balloons would be dominated by the cost of maintaining a launch crew in the field, not by the cost of the Tracers.

At the end of the Phase I and Phase II reports, the authors concluded that an Adjustable Buoyancy Tracer Balloon meeting the design goals is both technically and economically feasible. Phase III continues to confirm that conclusion. It remains to be demonstrated, however, that those design goals have in fact been fully met. Nevertheless, the Tracer system is already a useful atmospheric research tool.

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APPENDIX A

SUMMARY OF RELEVANT EQUATIONS

Standard Atmosphere

Most of the relationships derived in Phase I of the project assumed a standard atmosphere. For reference, the expressions used to represent the pressure P, density ρ, and temperature T of the air as a function of altitude z below the tropopause in a U.S. Standard Atmosphere are given below (Morris, 1975):

$$P = P_o \left(1 - \frac{\alpha}{T_o} z\right)^{\frac{Mg}{\alpha R}} \qquad \text{(A-1)}$$

$$\rho = \rho_o \left(1 - \frac{\alpha}{T_o} z\right)^{\frac{Mg}{\alpha R} - 1} \qquad \text{(A-2)}$$

$$T = T_o \left(1 - \frac{\alpha}{T_o} z\right) \qquad \text{(A-3)}$$

where

g = 9.807 m/s^2, acceleration due to gravity.

M = 28.96 kg/(kg - mol), average molecular weight of air.

P_o = 1013.25 millibars or 1.01325 x 10^5 N/m^2(Pa).

R = 8314.3 J/K (kg - mol), universal gas constant; if pressures expressed in mb, then 83.143.

T_o = 288.15 K.

z = altitude in m MSL, or more strictly, "geopotential meters".

α = 6.5 x 10^{-3} K/m, standard lapse rate.

ρ_o = 1.2250 kg/m^3.

$\frac{Mg}{\alpha R}$ = 5.255.

$\frac{g}{T_o}$ = 2.256×10^{-5} m^{-1}

Other Definitions

L = gross lift (Newtons); if divided by the acceleration due to gravity, units become kg (force).

L_s = gross lift of a slack balloon ($P_s = 0$).

L_R = gross required lift to make system neutrally buoyant at initial altitude z_o and superpressure P_{so}.

m = mass of balloon system exclusive of gas in balloon (kg).

P_a = ambient pressure of air at balloon altitude, typically expressed in mb.

P_b = absolute gas pressure in balloon, typically expressed in mb.

P_s = superpressure = $P_b - P_a$; typically expressed in mb.

P_{so} = superpressure at altitude z_o; initial superpressure.

S = pumping or valving flow rate (m^3/s).

V = volume of balloon (m^3) (presumed constant).

z = the equilibrium altitude of the balloon in m above mean sea level (MSL).

z_m = maximum altitude attainable; ceiling altitude.

z_o = altitude at which superpressure is set to P_{so}.

ρ_a = density of the ambient air at the altitude of the system (kg/m^3).

ρ_b = average density of gas contained in balloon (kg/m^3).

γ = lapse rate = $-dT/dz$ (K/m)

Pumpdown Velocity (v_p)

The rate at which the equilibrium altitude of the balloon (z) can be changed by pumping or valving in a standard atmosphere:

$$v_p = \frac{dz}{dt} = -1.042 \times 10^4 \frac{S}{V} (1 - 2.256 \times 10^{-5} z) \qquad \text{(A-4)}$$

In a nonstandard atmosphere, with an arbitrary lapse rate γ, the pumpdown velocity is given by:

$$v_p = -ST_a/(V\,(3.416 \times 10^{-2} - \gamma)) \qquad \text{(A-5)}$$

Change of Equilibrium Altitude Resulting from an Increment in Payload Mass

From B-4 and B-5, one can infer the change in equilibrium altitude dz resulting from an increment dm in payload mass. Taking on additional air ballast is equivalent to increasing the payload mass. Here dm = $S\rho_a$ dt, so

$$\frac{dz}{dm} = \frac{-8.506 \times 10^3}{V} (1 - 2.256 \times 10^{-5} z)^{-3.255} \qquad \text{(A-6)}$$

in a standard atmosphere, or

$$\frac{dz}{dm} = -2.871\, T_a{}^2 \,/\, (P_a V\,(3.416 \times 10^{-2} - \gamma)) \qquad \text{(A-7)}$$

in an arbitrary atmosphere.

Superpressure As A Function of Equilibrium Altitude

$$P_s = 2.396 \times 10^4 \frac{C}{V} (1 - 2.256 \times 10^{-5} z) \qquad \text{(A-8)}$$

and

$$\frac{dP_s}{dz} = -.541 \frac{C}{V} \qquad \text{(A-9)}$$

Using the expression for P_s, one can evaluate C.

$$C = \frac{VP_{so}}{2.396 \times 10^4 (1 - 2.256 \times 10^{-5} z_o)} \tag{A-10}$$

Effect of Temperature Swing on Balloon Pressure

$$\Delta P = 3.52 ((1 - 2.256 \times 10^{-5} z)^{4.255} + 83.14 \frac{C}{V}) \Delta T \tag{A-11}$$

Energy Required for Pumpdown per Unit Altitude Change

dW/dz is expressed in Joules/m; note that 1 Joule/s is a Watt.

$$\frac{dW}{dz} = \frac{9.60 \times 10^{-3} P_{so} V}{(1 - 2.256 \times 10^{-5} z_o)} \tag{A-12}$$

Required Lift L_R

To fill the balloon properly, one first puts in helium until the gross lift is measured to be L_R as given below. Then, one seals the inner balloon, and inflates the outer balloon with air, until the desired initial superpressure P_{so} is reached. At that point, the balloon system, after attachment of the payload, should be approximately neutrally buoyant.

$$L_R = (m + M \frac{P_{so} V}{RT}) g \tag{A-13}$$

Ceiling Altitude z_m

$$z_m = \frac{1}{2.256 \times 10^{-5}} (1 - (\frac{0.1604 (L_s/g) + m}{1.225 V})^{0.2350}) \tag{A-14}$$

If the balloon was filled optimally, then L_s becomes L_R, the required lift.

Terminal Rate of Descent on Cutdown, v_T

A good approximation to the terminal fall velocity of the Tracer Balloon after cutdown is given by:

$$v_T = \sqrt{(m_L g/b)} \qquad \text{(A-15)}$$

where

$$b = (1/2)\rho_a C_D A_D \qquad \text{(A-16)}$$

and where

$$m_L = 10.6\ M\ C\ A\ (\ \rho_a^{5/6}/M)(L_S/(.862\ M\ g))^{1/6} t \qquad \text{(A-17)}$$

Here t is time in seconds since cutdown device firing, C_D is the drag coefficient of the balloon (we may presume 0.5), A_D is the cross sectional area of the balloon, A is the area of the hole produced by the electric match (about 1 cm^2), C is the orifice coefficient (between 0.5 and 1.0), and as before, L_S is the slack lift of the balloon. The remaining symbols have been previously defined. Note that the cross sectional area of the balloon can be presumed to be constant -- even in a descent from 500 mb, the balloon looses relatively little gas. Typical descent rates are 4-5 m/s.

Expression for Determining Balloon Volume V as a Function of Superpressure

$$V = (L_S/g - L/g)\ R\ T\ /\ (M\ P_s) \qquad \text{(A-18)}$$

Here L_S is the slack lift of the balloon, and L is the actual lift at superpressure P_s. The other quantitites are as previously defined.

APPENDIX B

REVISED SECOND GENERATION BALLOON DESIGN

1. Letter dated October 17, 1984, from Robert M. Enderson, Raven Industries, Inc., to Sandia National Laboratories, Attention Bernard Zak....................................69

2. Changes considered desirable in the second generation balloon design..72

RAVEN INDUSTRIES, INC.

RAVEN

PO Box 1007 Sioux Falls, South Dakota 57117-1007
Telephone (605) 336-2750 TWX910-660-0306

October 17, 1984

Sandia National Laboratories
Applied Atmospheric Research Division
Albuquerque, NM 87185

Attention: Mr. Bernard Zak

Subject: Raven Industries, Inc. Letter Proposal
No. ATD 1084122 For a Variable Density Balloon

Dear Mr. Zak:

Raven is pleased to present this proposal in response to your requirement as discussed during your visit on 29 August.

The basic requirement is for a superpressure balloon capable of supporting a twelve pound payload at an altitude of 500 mb. Additional related requirements are as follows:

- vent fitting at top apex
- full volume bladder
- 3.5 inch inside diameter base fitting (capable of inserting persons arm)
- helium inflation through base fitting
- handling lines
- rain skirt

Raven proposes balloon Model No. S-P3.0-D11.2. The balloon has a diameter of 11.2 feet and is proposed to be fabricated from polyester film. The balloon would be fabricated from twelve gores and incorporate a polyurethane film bladder.

Design details of the proposed balloon are discussed in the following paragraphs.

BALLOON MATERIAL

Polyester film with a thickness of 3.0 mils is the primary film proposed. Raven has this film in stock, and for economic reasons it has to be the primary choice. The computed stress at a superpressure of 80 mb. is 12992 psi, slightly higher than the targeted stress of 12000 psi.

Raven will attempt to locate a stock source of film of a heavier gauge than 3.0 mils before the balloon design is finalized. If a heavier gauge film, up to 4.0 mils, can be located and at acceptable cost, the design will be modified as necessary. A slightly larger balloon would result. A 4.0 mil film would reduce the stress to approximately 10000 psi.

BLADDER MATERIAL

The proposed bladder material is 1.0 mil polyurethane film. The urethane film is proposed over polyethylene because of its lower helium permeability rate. The measured helium permeability rate of 1.5 mil polyethylene is 5.58 liters/m^2/24 hours, that of 1.0 mil urethane film 3.83.

The selection of urethane film is contingent upon acceptable deployment of the bladder being obtained in tests. Polyethylene will be utilized if deployment of a urethane film bladder is unacceptable.

The bladder will be secured to the sphere with the vent fitting at the top apex. This configuration will be the same as in the similar balloons previously supplied.

The bladder will incorporate an inflation tube that will be accessible through the base fitting and of a compatible diameter. Inflation of the balloon/bladder assembly through the base fitting will alleviate the necessity of turning the balloon via the handling lines and the associated stress. The inflation tube can be sealed with a single overhand knot when the inflation is completed.

BASE FITTING

A basic requirement of the end fitting is that it is of a size sufficiently large to allow a persons arm to be extended into the balloon. This will require a minimum inside diameter of the fitting of approximately 3.5 inches. This diameter will be more than adequate to accommodate the 2.25 inch X 4.0 inch involved circuit board.

A threaded fitting and a clamp configuration for securing the fitting to the balloon will both be evaluated. The fitting, with either basic configuration, will incorporate a threaded cap.

LOAD SUSPENSION

The load suspension will consist of three load patches installed on the surface of the main shell with suitable nylon lines extending to a confluence point.

Two load patches will additionally be installed near the top of the balloon for handling the balloon. The strength of the patches will be increased over those previously supplied.

RAIN SKIRT

The balloon will incorporate a rain skirt. The skirt will be installed at a 120° included angle location.

TERMINATION

The proposed balloon will incorporate a 3-wire twisted conductor from the base to the top of the balloon.

The proposed price for the balloon is $1,537.00 each in a quantity of ten. The price is F.O.B. Sioux Falls, S.D. Terms are net thirty days.

Included in the price is an allowance for engineering and testing.

If you have any questions regarding this proposal, please contact me.

Sincerely,

RAVEN INDUSTRIES, INC.

Robert M. Enderson
Sales Engineer
Applied Technology Division

RME/js

Changes Considered Desirable in the Second Generation Balloon Design

- Helium inflation of the inner balloon should continue to be through the top fitting, rather than as proposed earlier.
- The first generation balloon was a slightly prolate spheroid. One should investigate the possibility of making the second generation balloon an oblate spheroid. If the height of the balloon is kept low, it facilitates finding a suitable inflation shelter. Width is less of a problem.
- The bottom fitting must be designed to protect the inner balloon from abrasion as it is installed in the outer balloon during the manufacturing process. Sharp mylar or any other edges must be covered with a smooth surface.
- Either 3.5 or 4 mil bilaminated polyester is preferred for the larger balloon if the cost is not too high. This would permit a higher maximum superpressure, and hence, a larger operating temperature range above and below ambient.
- While special care is required to properly seal the top fitting during installation, the fitting must not be emplaced permanently with adhesive. The inner balloon must continue to be removable for repair or replacement if necessary.
- No wires should be installed on the balloon by the manufacturer. This can be done more effectively by the users.
- The circular seal between the gore structure and the circular mylar piece at the top of the balloon must be substantially reinforced. It is the weakest part of the balloon.

APPENDIX C

MODIFIED OPERATIONAL PROTOTYPE SCHEMATIC DIAGRAMS AND PARTS LISTS

1. Diagrams

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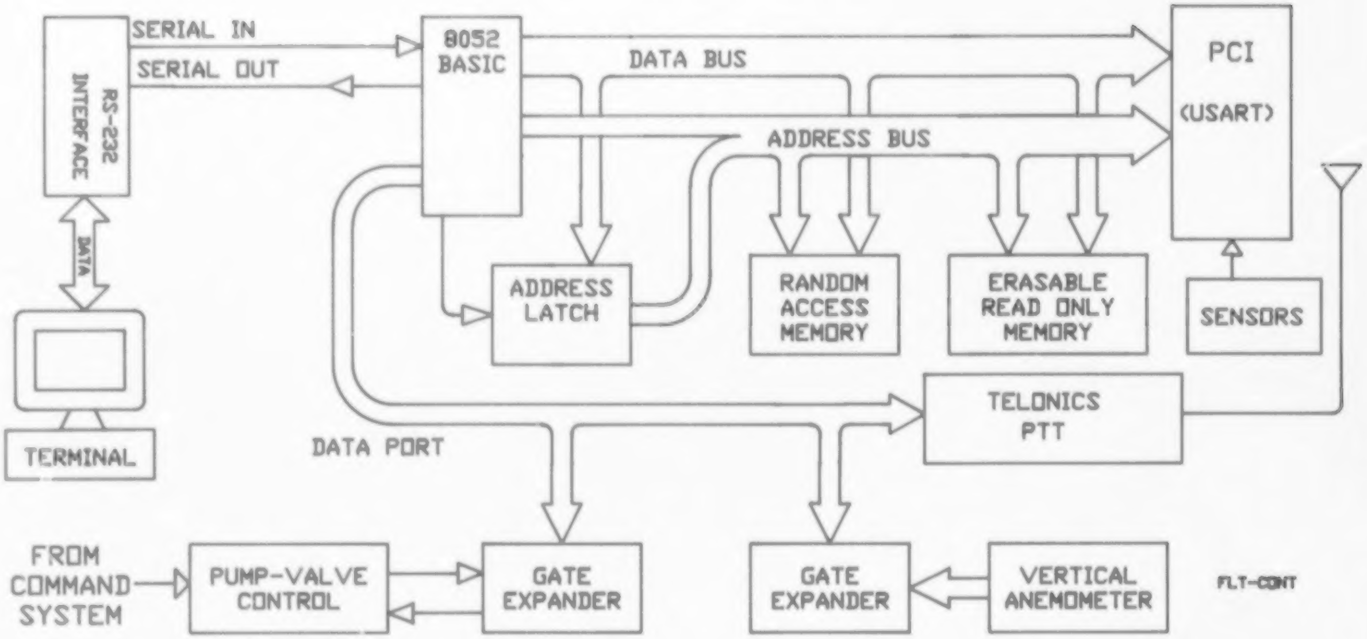
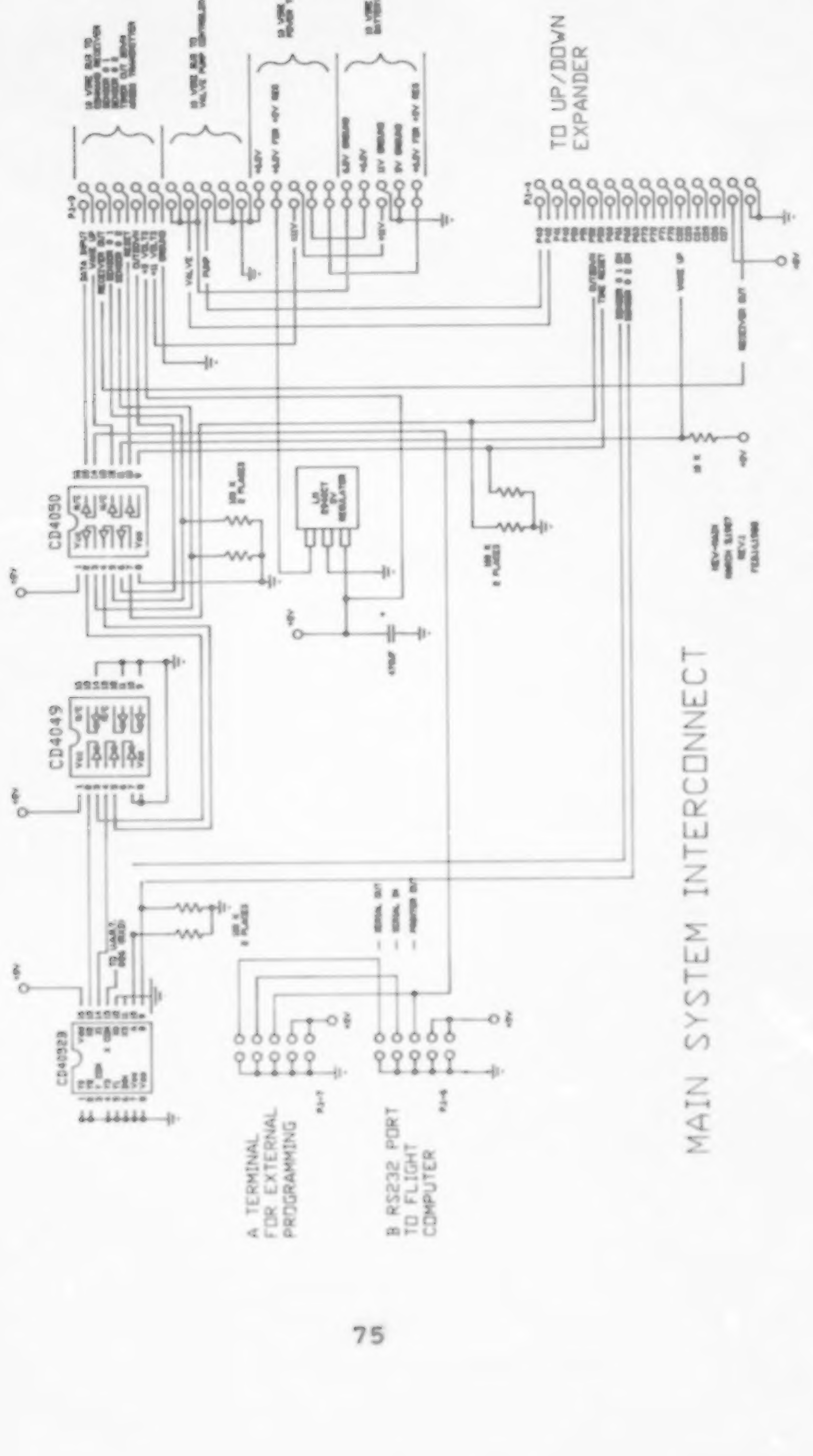
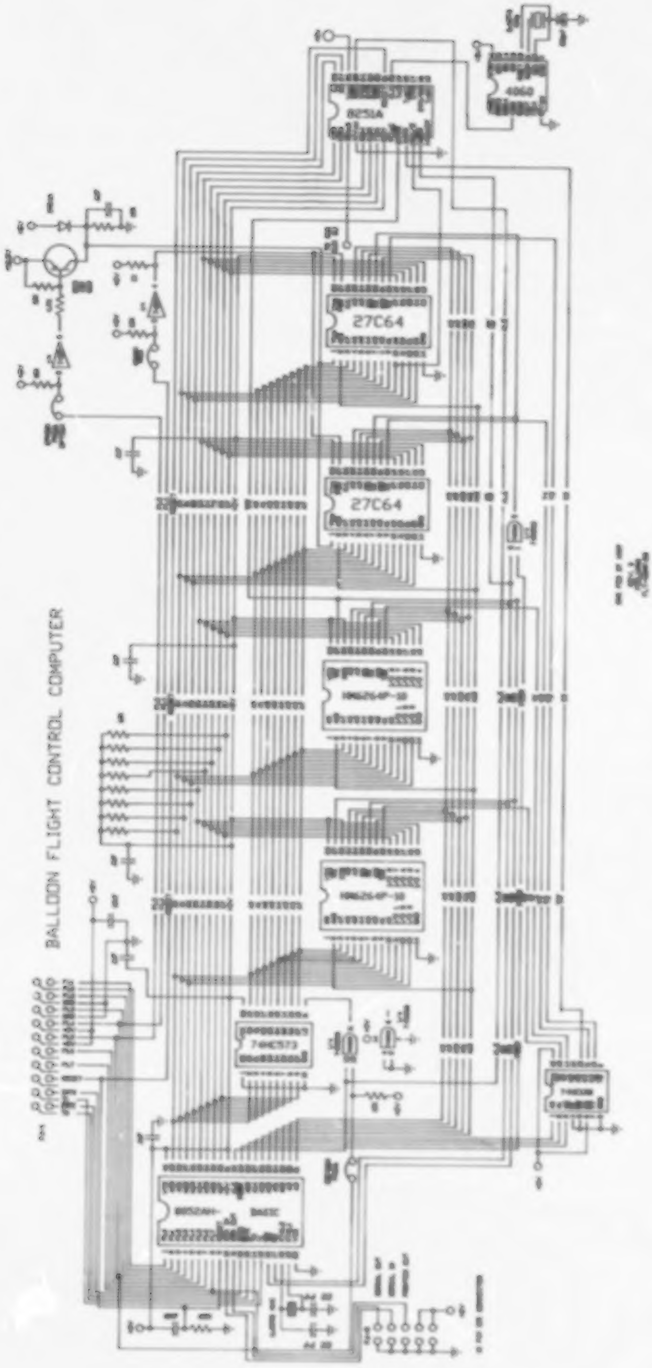
c. Payload/Terminal Interface Board..................86

2. Parts Lists...87

TRACER BALLOON
COMPUTER CONTROL SYSTEM

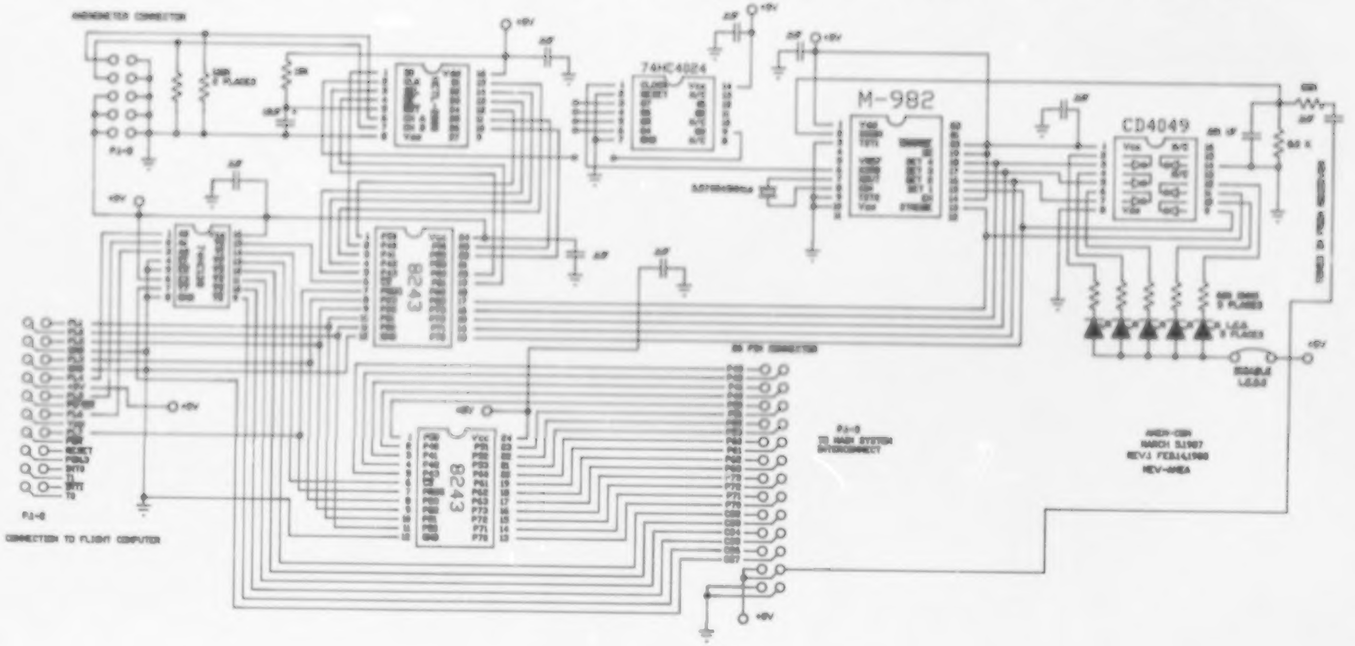

SERIAL IN
SERIAL OUT
RS-232 INTERFACE
DATA
TERMINAL
8052 BASIC
DATA BUS
ADDRESS BUS
PCI (USART)
ADDRESS LATCH
RANDOM ACCESS MEMORY
ERASABLE READ ONLY MEMORY
SENSORS
TELONICS PTT
DATA PORT
FROM COMMAND SYSTEM
PUMP-VALVE CONTROL
GATE EXPANDER
GATE EXPANDER
VERTICAL ANEMOMETER
FLT-CONT


CD4050
CD4049
CD4052B
TO UP/DOWN EXPANDER
A TERMINAL FOR EXTERNAL PROGRAMMING
B RS232 PORT TO FLIGHT COMPUTER
MAIN SYSTEM INTERCONNECT

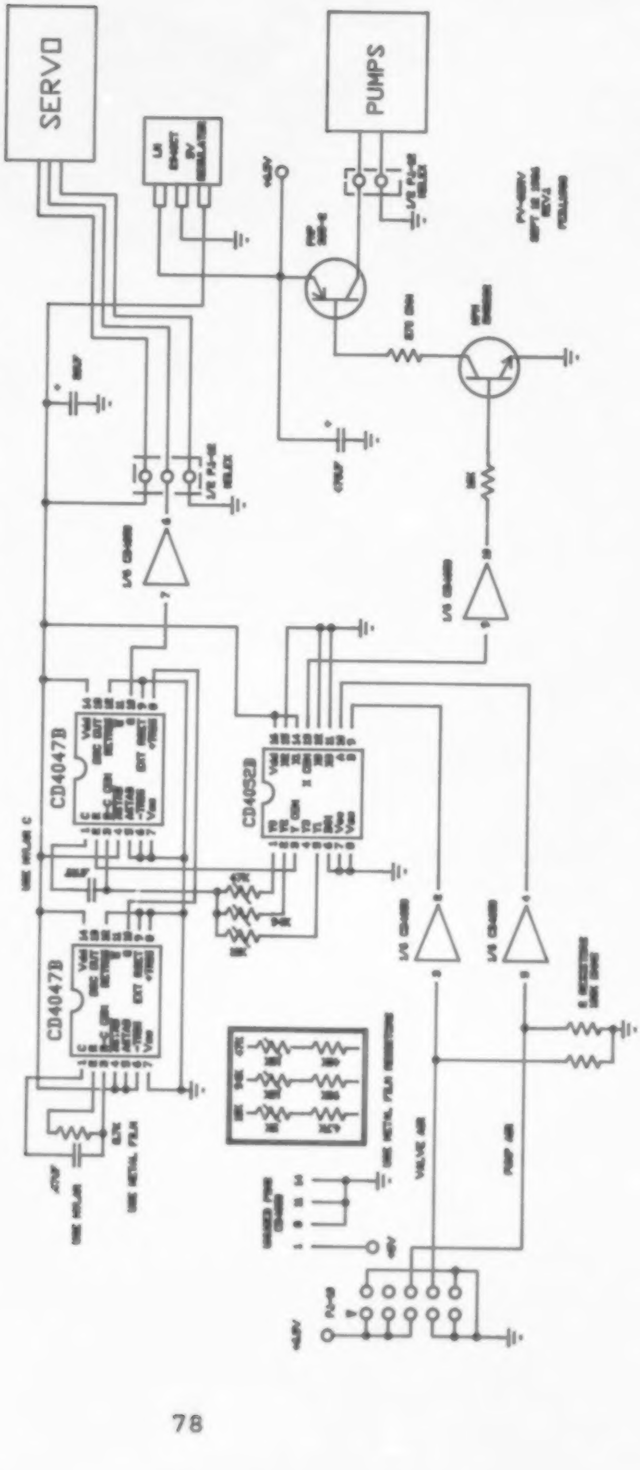

BALLOON FLIGHT CONTROL COMPUTER

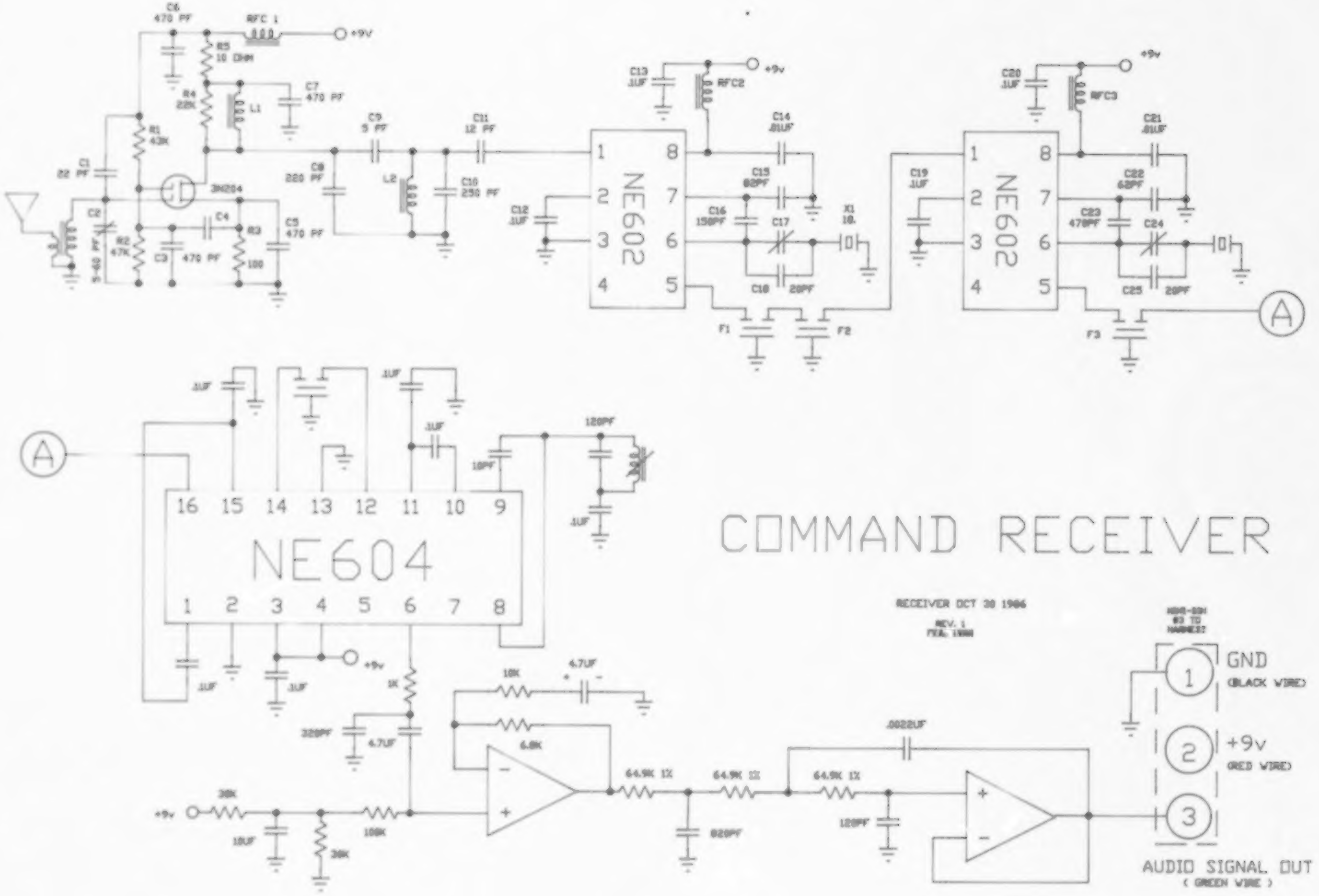
8251A
4060
27C64
27C64
HM6264P-10
HM6264P-10
74HC573
8052AH-BASIC

ANEMOMETER DECODER AND COMPUTER INTERFACE

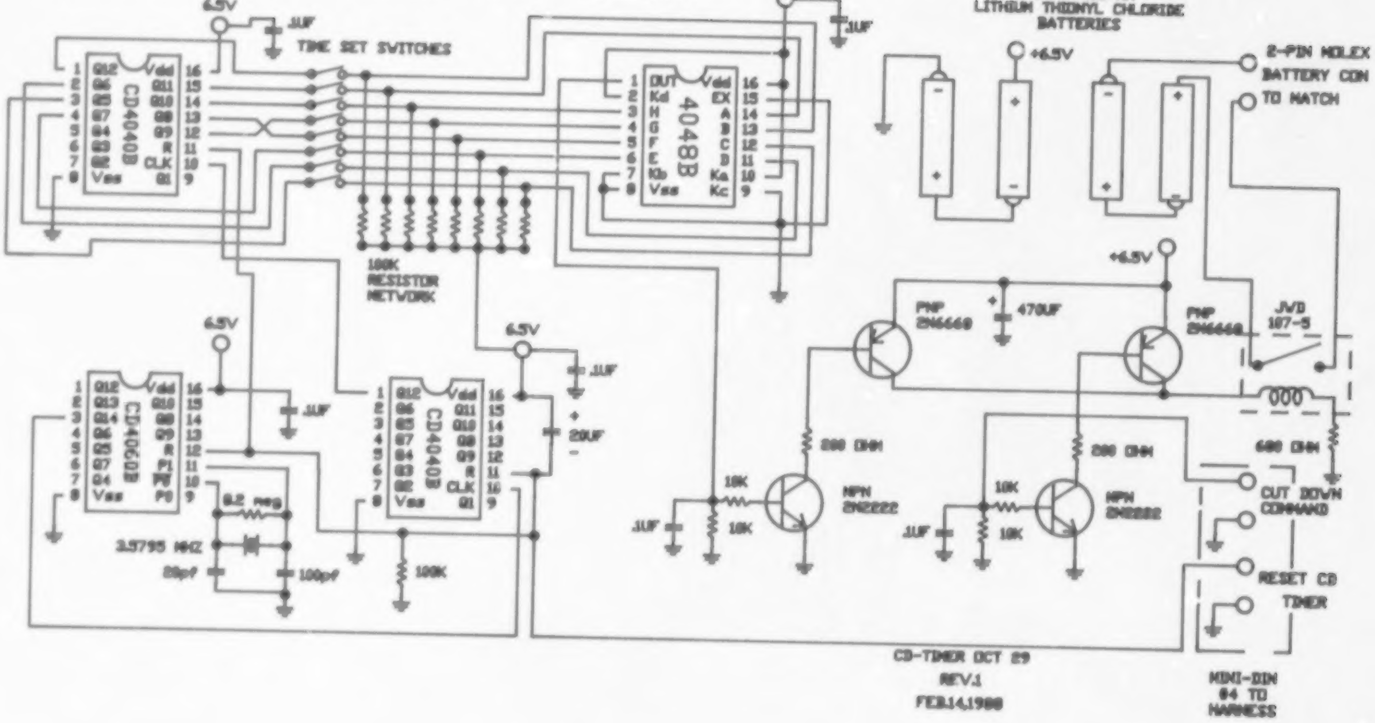

ANEMOMETER CONNECTOR
+5V
74HC4024
M-982
CD4049
8243
8243
74HC138
HCTL-2000
P1-8
CONNECTION TO FLIGHT COMPUTER
RESET
T0
50 PIN CONNECTOR
DISABLE LEDS
5 PLACES
ANEM-CBN
MARCH 5,1987
REV.1 FEB14,1988
MEV-AMEA

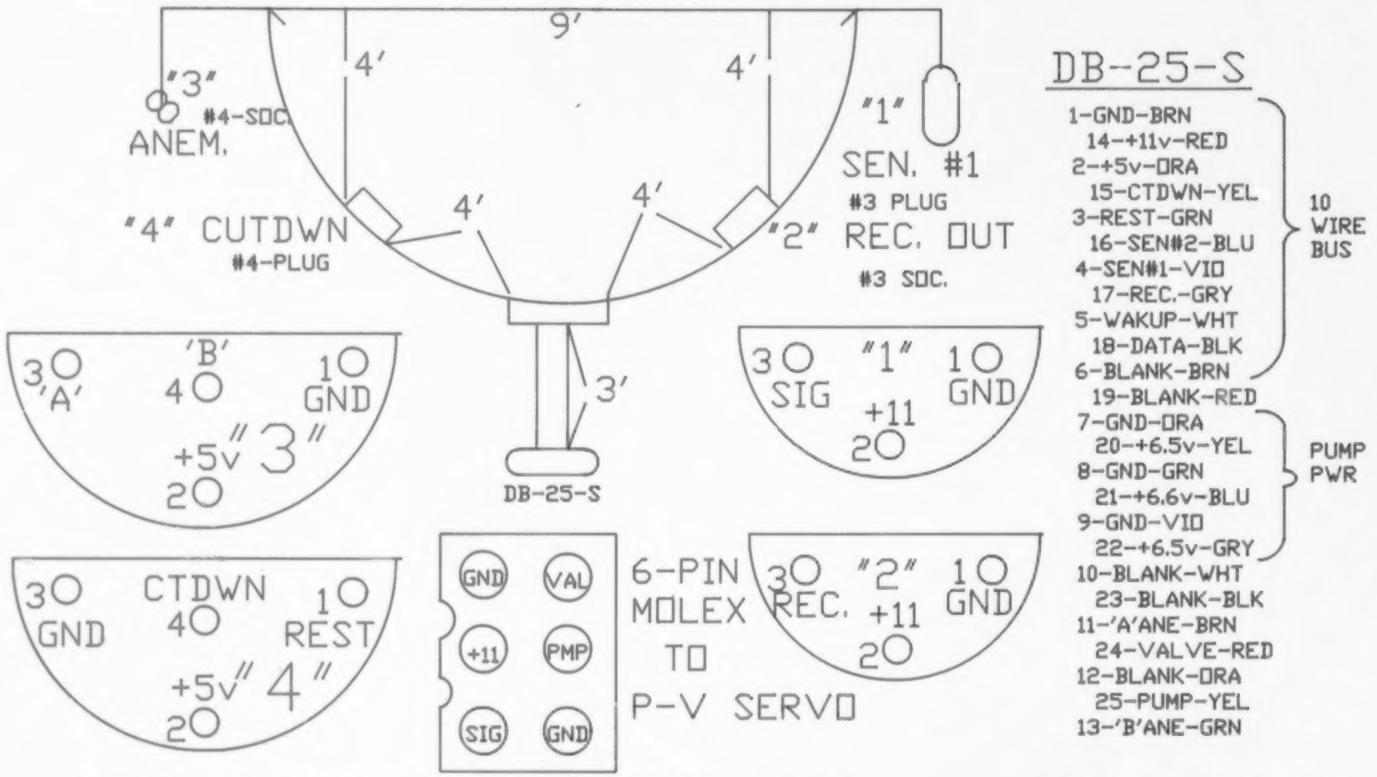
PUMP AND VALVE SERVO


SERVO
PUMPS
CD4047B
CD4047B
CD4052B


COMMAND RECEIVER
RECEIVER OCT 30 1986
REV. 1
FEB. 1988
C6 470 PF
RFC 1
+9V
R5 10 OHM
R4 22K
L1
C7 470 PF
R1 43K
C1 22 PF
3N204
C2 5-60 PF
R2 47K
C3 470 PF
C4
R3 100
C5 470 PF
C8 220 PF
C9 5 PF
L2
C10 250 PF
C11 12 PF
C12 .1UF
C13 .1UF
RFC2
+9v
NE602
C14 .01UF
C15 68PF
C16 150PF
C17
C18 20PF
X1 10.
F1
F2
C19 .1UF
C20 .1UF
RFC3
C21 .01UF
C22 68PF
C23 470PF
C24
C25 20PF
F3
A
NE604
.1UF
10PF
120PF
1K
320PF
4.7UF
10K
6.8K
64.9K 1%
820PF
120PF
.0022UF
30K
10UF
100K
GND
(BLACK WIRE)
+9v
(RED WIRE)
AUDIO SIGNAL OUT
(GREEN WIRE)

INDEPENDENT TIMER CUT DOWN

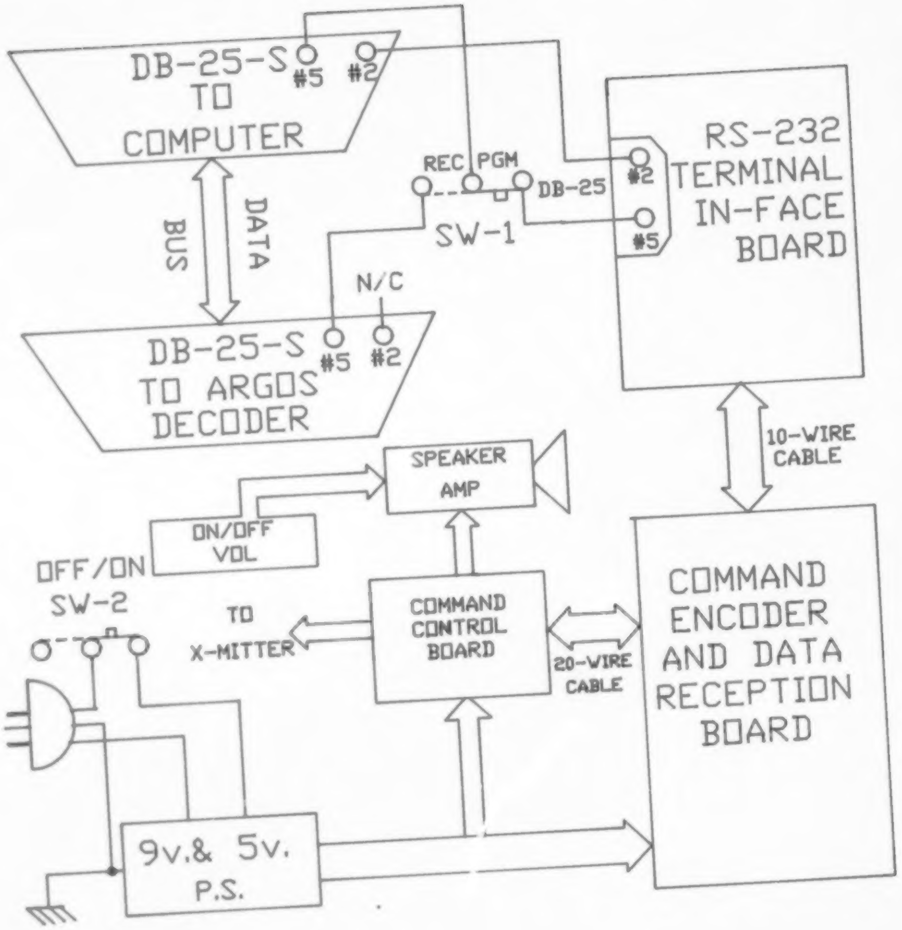

6.5V
.1UF
TIME SET SWITCHES
CD4040B
4048B
CD4060B
100K RESISTOR NETWORK
ALTUS AL2-AA LITHIUM THIONYL CHLORIDE BATTERIES
+6.5V
2-PIN MOLEX BATTERY CON TO MATCH
PNP 2N6660
470UF
JVD 107-5
200 OHM
NPN 2N2222
10K
680 OHM
CUT DOWN COMMAND
RESET CD TIMER
MINI-DIN #4 TO HARNESS
20UF
8.2 meg
3.5795 MHZ
20pf
100pf
100K
CD-TIMER OCT 29
REV.1
FEB.14.1988


9'
4'
4'
4'
4'
3'
"3"
#4-SOC.
ANEM.
"4" CUTDWN
#4-PLUG
"1"
SEN. #1
#3 PLUG
"2" REC. OUT
#3 SOC.
DB-25-S
3O 'A'
'B' 4O
1O GND
+5v "3"
2O
3O SIG
"1"
1O GND
+11
2O
3O GND
CTDWN 4O
1O REST
+5v "4"
2O
GND
VAL
+11
PMP
SIG
GND
6-PIN MOLEX TO P-V SERVO
3O REC.
"2"
1O GND
+11
2O
DB-25-S
1-GND-BRN
14-+11v-RED
2-+5v-ORA
15-CTDWN-YEL
3-REST-GRN
16-SEN#2-BLU
4-SEN#1-VIO
17-REC.-GRY
5-WAKUP-WHT
18-DATA-BLK
6-BLANK-BRN
19-BLANK-RED
7-GND-ORA
20-+6.5v-YEL
8-GND-GRN
21-+6.6v-BLU
9-GND-VIO
22-+6.5v-GRY
10-BLANK-WHT
23-BLANK-BLK
11-'A'ANE-BRN
24-VALVE-RED
12-BLANK-ORA
25-PUMP-YEL
13-'B'ANE-GRN
10 WIRE BUS
PUMP PWR

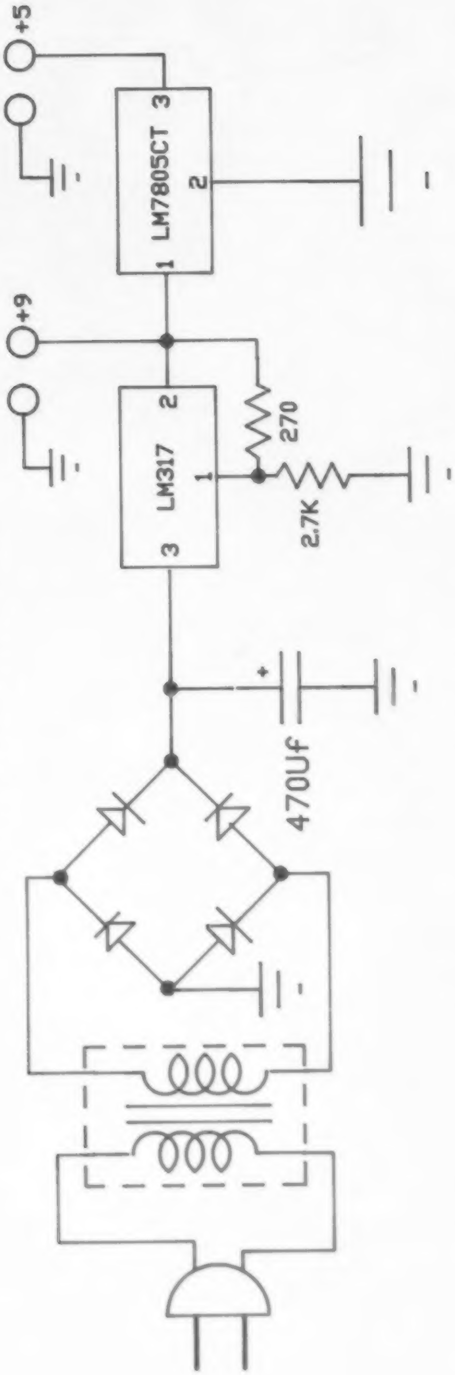
ENVELOPE HARNESS

ENV-HARN
FEB. 1988

COMMAND ENCODER AND DATA INTERFACE ASSEMBLY


DB-25-S TO COMPUTER
#5
#2
DATA
BUS
DB-25-S TO ARGOS DECODER
#5
#2
N/C
REC
PGM
DB-25
SW-1
RS-232 TERMINAL IN-FACE BOARD
#2
#5
10-WIRE CABLE
COMMAND ENCODER AND DATA RECEPTION BOARD
20-WIRE CABLE
COMMAND CONTROL BOARD
SPEAKER AMP
ON/OFF VOL
TO X-MITTER
OFF/ON
SW-2
9v.& 5v. P.S.

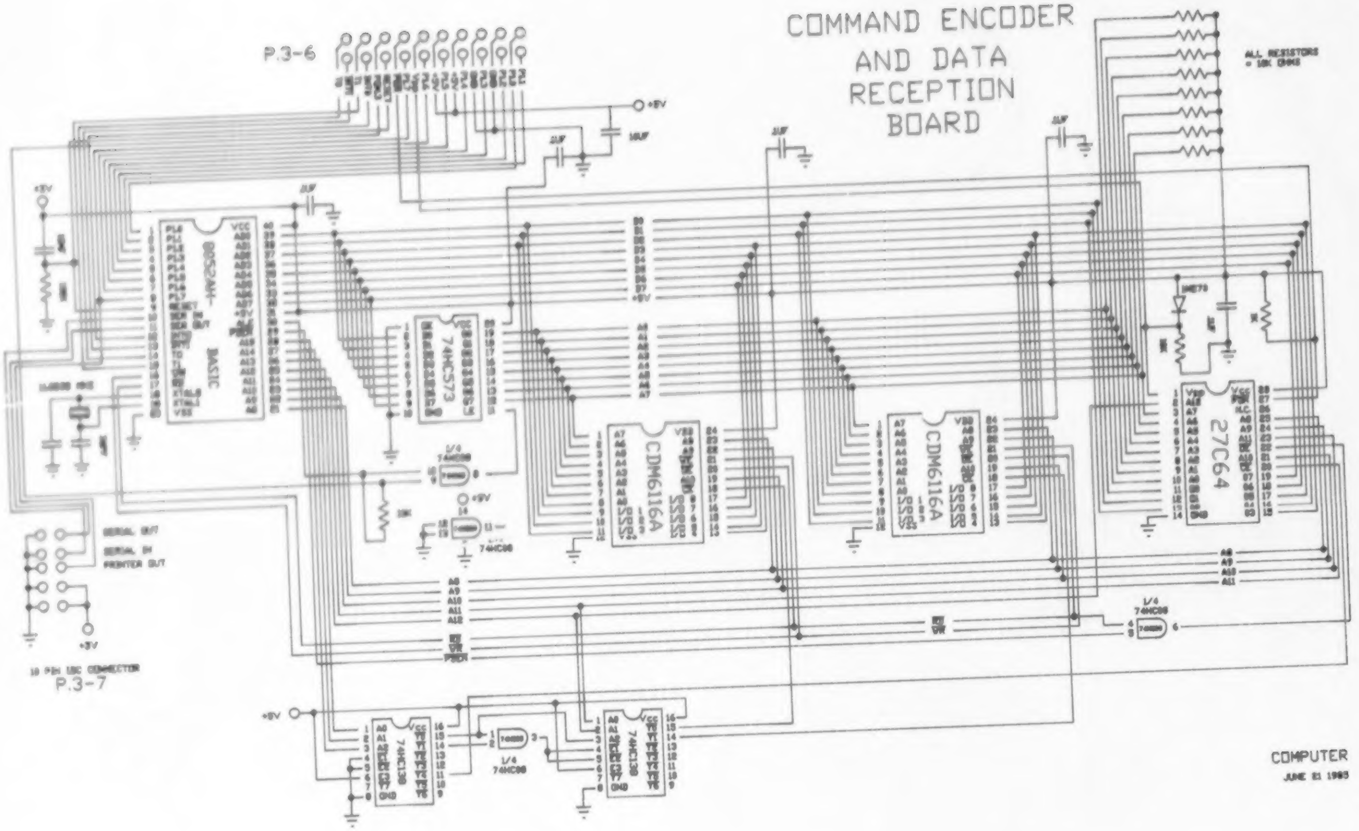
GREY-BOX
FEB. 1988



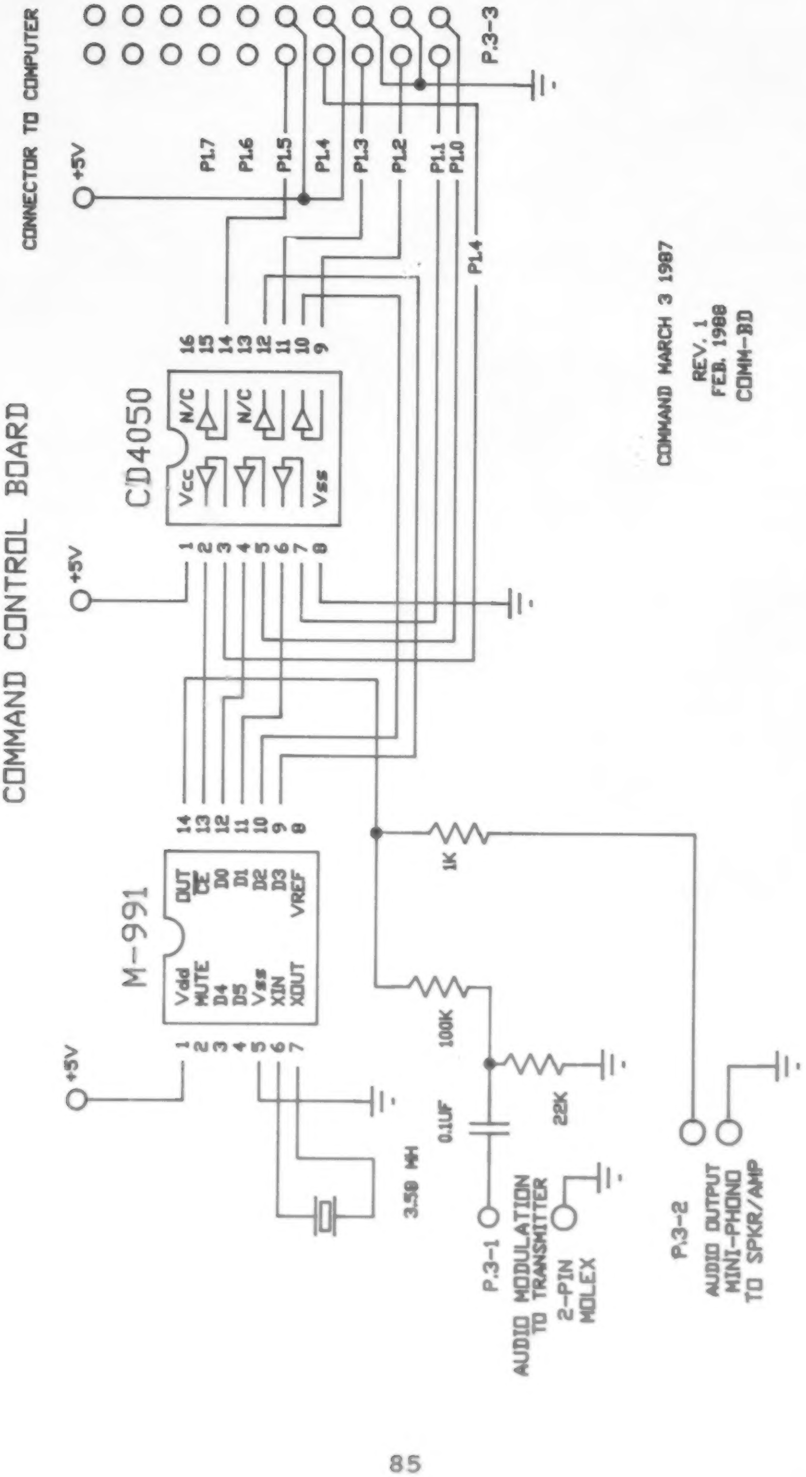
+5
LM7805CT
1
2
3
+9
LM317
1
2
3
270
2.7K
+
470Uf

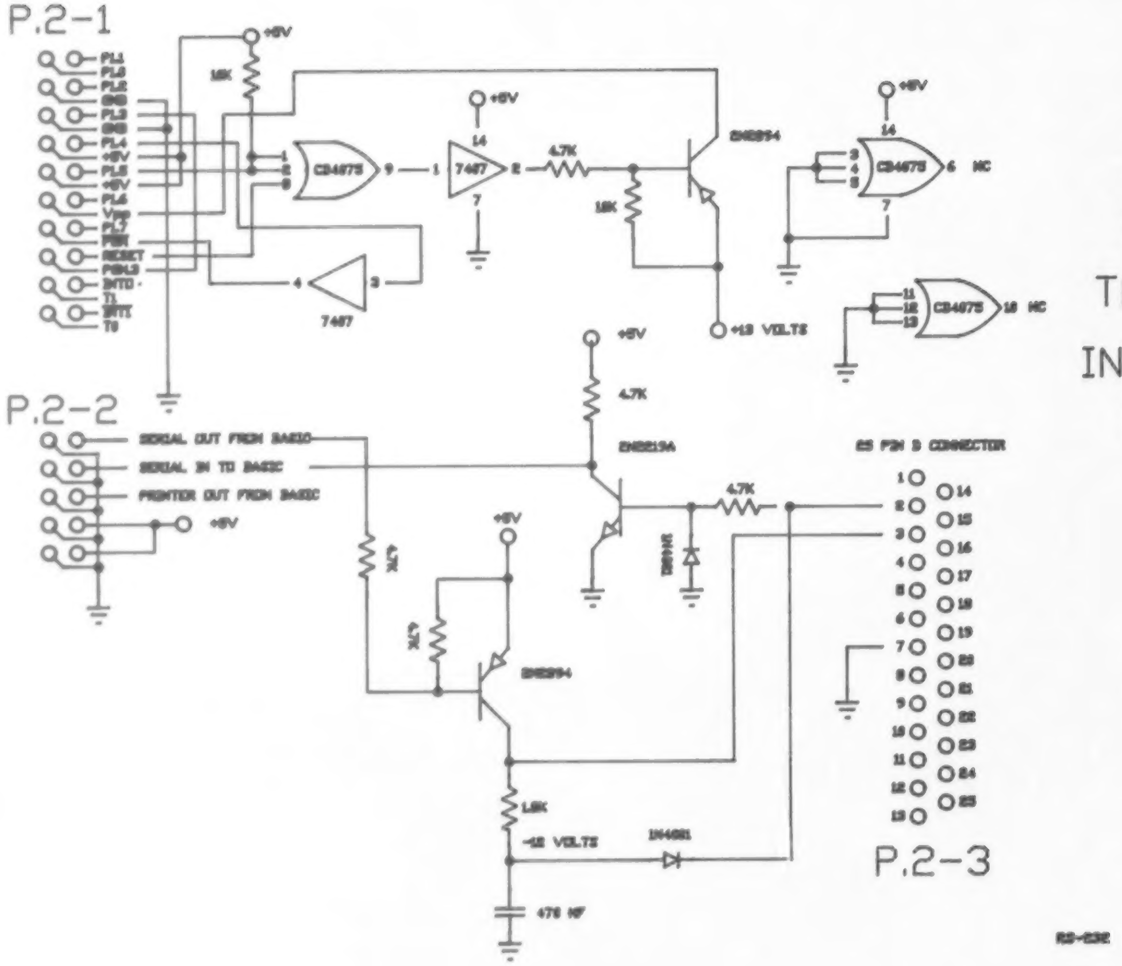
COM.ENCODER/DATA REC. P.S.

COMMAND ENCODER AND DATA RECEPTION BOARD


P.3-6
+5V
10UF
.1UF
8052AH- BASIC
74HC573
CDM6116A
CDM6116A
27C64
ALL RESISTORS = 10K OHMS
1N270
10K
1/4 74HC08
A8
A9
A10
A11
A12
RD
WR
PSEN
74HC138
74HC138
SERIAL OUT
SERIAL IN
PRINTER OUT
+5V
10 PIN IDC CONNECTOR
P.3-7
COMPUTER
JUNE 21 1985

COMMAND CONTROL BOARD


CONNECTOR TO COMPUTER
+5V
P1.7
P1.6
P1.5
P1.4
P1.3
P1.2
P1.1
P1.0
P.3-3
P1.4
CD4050
Vcc
Vss
N/C
N/C
1 2 3 4 5 6 7 8
16 15 14 13 12 11 10 9
M-991
Vdd
MUTE
D4
D5
Vss
XIN
XOUT
OUT
CE
D0
D1
D2
D3
VREF
1 2 3 4 5 6 7
14 13 12 11 10 9 8
1K
100K
22K
0.1UF
3.58 MH
P.3-1
AUDIO MODULATION TO TRANSMITTER
2-PIN MOLEX
P.3-2
AUDIO OUTPUT MINI-PHONO TO SPKR/AMP
COMMAND MARCH 3 1987
REV. 1
FEB. 1988
COMM-BD


P.2-1
PL1
PL0
PL2
GND
PL3
GND
PL4
+5V
PL5
+5V
PL6
PL7
RESET
T1
T0
+5V
10K
CD4075
7407
+5V
4.7K
10K
2N2894
+12 VOLTS
+5V
CD4075
NC
CD4075
NC
P.2-2
SERIAL OUT FROM BASIC
SERIAL IN TO BASIC
PRINTER OUT FROM BASIC
+5V
+5V
4.7K
2N2219A
4.7K
1N4001
4.7K
4.7K
+5V
4.7K
2N2894
1.8K
-12 VOLTS
1N4001
470 MF
25 PIN D CONNECTOR
P.2-3
RS-232

RS-232
TERMINAL
INTERFACE
BOARD

ADJUSTABLE BUOYANCY BALLOON

COMPONENTS NEEDED FOR GROUND STATION

- 1.) COMPUTER
  - A.) NEC MODEL APCIII OR EQUIVALENT
    - a.) Software
      - 1.) SYSTEM (MS.-DOS)
      - 2.) "GROUND" Program
- 2.) MONITOR
  - A.) NEC MODEL APC-H131 OR EQUIVALENT

- 3.) PRINTER
  - A.) EPSON FX-85 OR EQUVALENT
    - a.)Parallel Type Printer

- 4.) COMMAND ENCODER AND DATA RECEPTION INTERFACE UNIT
  - A.) SUBASSEMBLIES REQUIRED
    - 1.) BOARDS
      - a.) 9-5-PS
      - b.) COMM-BD
      - c.) RS-232 INTERFACE BD
      - d.) COMMAND ENCODER AND DATA RECEPTION BD
    - 2.) AMPLIFIER (MAY BE COSTOM BUILD)
      - a.) ARCHER MINI AMPLIFIER-SPEAKER OR EQUIV.
    - 3.) SWITCHES
      - a.) SPST (1ea.)
      - b.) SPDT (1ea.)
    - 4.) CORDS AND CABLES
      - a.) AC LINE CORD 30"
      - b.) 2 WIRE DC POWER CORD 6"
      - c.) 2 WIRE AUDIO w/MINI-PHONO JACK 6"
      - d.) 2 WIRE AUDIO MOD. w/MIC PLUG 30"
      - e.) 20 COND. RIBBON w/2 Dip conn. 6"
      - f.) 10 COND. RIBBON w/2 Dip conn. 6"
      - g.) 25 COND. RIBBON w/2 DB-25-S & 1 DB25-P
    - 5.) SOFTWARE
      - a.) "TRANSMITTER" Program
    - 6.) CASE

- 5.) ARGOS RECEIVER AND DECODER SYSTEM
  - A.) HANDAR MODEL 401C OR TELONICS MODEL TSUR-B
    - a.) 401.65 MHz Receiver Frequency

- 6.) ANTENNA
  - A.)TELONICS YAGI ANTENNA FOR 400 MHz

- 7.) CABLES
  - A.) RS-232 TYPE (2 ea. Needed)
    - a.) DB-25-P
  - B.) RG-8/U OR EQUIVALENT

8.) TRANSMITTER
    A.) ICOM MODEL IC-745 OR EQUIVALENT
        a.) Capable of 13.8035 MHz FM Transmission
            1.) Or other frequency assigned to specific user by F.C.C.

9.) ANTENNA
    A.) HF TYPE
        a.) Capable of 13.805 MHz Transmission
            1.) (see note on frequency)

10.) CABLE
    A.) RG-8/U OR EQUIVALENT

11.) ANTENNA TUNER
    A.) B&W MODEL VS300A

FLIGHT PACKAGE
PARTS LIST

COMPONENTS NEEDED FOR FLIGHT PACKAGE

FLIGHT PACKAGE MAIN MODULE

1.) STYROFOAM PACKAGE
    A.) CUSTOM BUILT

2.) SUBASSEMBLIES REQUIRED
    A.) BOARDS
        1.) FLIGHT CONTROL BD.
        2.) MAIN INTERFACE BD.
        3.) POWER AND MUX BD.
        4.) PUMP AND SERVO BD.
        5.) TELONICS PTT ASBY.

    B.) SOFTWARE
        1.) FLY-0222 (OR EQUIV.)
            a.) PROGRAM TO CONTAIN CORRECT COOEFFICIENTS FOR SENSORS USED.
        2.) MACHINE CODE PROGRAM
            a.) PROGRAM TO READ SENSOR INPUT

    C.) BATTERIES
        1.) ALTUS "C" SIZE (5ea.)
        2.) ALTUS "D" SIZE (2ea.)

    D.) CABLES
        1.) POWER DISTRIBUTION CABLE
            a.) 40 WIRE RIBBON w/40 Pin Dip conn.
                1.) 10 Pin Dip w/POWER RECEPTACLE AND PLUG
                2.) 10 Pin Dip for POWER INPUT
                3.) 10 Pin Dip for PUMP SERVO
            b.) 10 WIRE RIBBON
                1.) PUMP SERVO to INTERCONN.

        2.) INTERCONNECT CABLES
            a.) 26 WIRE RIBBON w/ 2ea.26 Pin Dip conn.
                1.)MAIN INFACE BD.to ANEM.DECODE & INFACE
            b.) 10 WIRE RIBBON w/2ea.10 Pin Dip conn.
                1.)MAIN INTERFACE BD. to RS-232 INTERFACE BD.
            c.) 10 WIRE RIBBON w/ 2ea.10 Pin Dip conn.
                1.)MAIN INTERFACE BD. to FLT. COMPUTER
            d.) 20 WIRE RIBBON w/ 2ea.20 Pin Dip conn.
                1.)FLT.COMPUTER BD.to ANEM.DECODE&INFACE BD.
            e.) 10 WIRE RIBBON w/ 1ea.10 Pin Dip conn.
                1.) ANEA. DECODE & INFACE BD. to INTERCONN.
            f.) 10 WIRE RIBBON
                1.) PUMP SERVO to INTERCONN.
            g.) 25 WIRE RIBBON w/ DB-25-S conn. (30")

- 1.) INTERCONN. to DB-25-S conn.
- h.) WIRE HARNESS for ENVELOPE
  - 1.) 25 WIRE RIBBON w/ DB-25-P (36")
    - A.) DB-25-P to HARNESS DISTRIBUTION
- i.) 4 WIRE RIBBON w/4 Pin Mini-Din conn.(8')
  - 1.)DIST. to ANEM. & CUTDOWN PKGS.
- j.) 3 WIRE RIBBON w/3 Pin Mini-Din conn.(8')
  - 1.) DIST. to SEN #1 & REC. PKGS.
- h.) 2 WIRE TWISTED PR. w/ 2 Pin Molex
  - 1.) CUTDOWN to ELECTRIC MATCH

- E.) ANTENNAS
  - 1.) ARGOS
    - a.) CUSTOM W/ BNC conn.

- F.) BASEPLATE
  - 1.) SUBASSEMBLIES REQUIRED
    - a.) BASEPLATE
    - b.) SERVO
      - 1.) FUBATA MOD. FP-S28
      - 2.) CUSTOM VALVE ACTUATOR CAM
    - c.) AIR VALVES (2ea.)
      - 1.) CLIPPARD MOD. MJV-2
    - d.) SENSOR
      - 1.) A.I.R. INTELLISONDE
        - A.) THERMISTOR
          - 1.) VIZ THERMOMETER
        - B.) HYGRISTOR
          - 1.) VIZ HYGRISTOR PN. 1286-162
    - e.) BASEPLATE BRACKET
      - 1.) CUSTOM BUILT

    - f.) INSTRUMENT PUMPS (3ea.)
      - 1.) GILIAN MOD 10079

INDEPENDENT TIMER-CUTDOWN

- 1.) STYROFOAM PACKAGE
  - A.) CUSTOM BUILT

- 2.) SUBASSEMBLIES REQUIRED
  - A.) BOARDS
    - 1.) TIMER-CD BD.

  - B.) BATTERIES
    - 1.) ALTUS "AA" SIZE (4 ea.)

  - C.) CABLES
    - 1.) 4 WIRE RIBBON w/ 4 Pin Mini-Din conn.
      - a.) HARNESS to CUTDOWN
    - 2.) 2 WIRE STRANDED (18ga.) w/ 2 Pin Molex (20')
      - a.) CUTDOWN to ELECTRIC MATCH

  - D.) VELCRO

1.) ATTACHMENT to ENVELOPE

RECEIVER

1.) PLASTIC PACKAGE

2.) SUBASSEMBLIES REQUIRED

- A.) BOARDS
  - 1.) RECEIVER BD.
    - a.) HOCK ENGINEERING

- B.) CABLES
  - 1.) 3 WIRE STRANDED w/ 3 Pin Mini-Din conn.

- C.) ANTENNA
  - 1.) 10' CO-AX
    - a.) CUSTOM BUILT

- D.) VELCORO
  - 1.) ATTACHMENT to ENVELOPE

SENSOR

1.) STYROFOAM PACKAGE
- A.) CUSTOM BUILT

2.) SUBASSEMBLIES REQUIRED

- A.) BOARDS
  - 1.) A.I.R. INTELLISONDE

- B.) THERMISTOR
  - 1.) VIZ TEMPERATURE SENSOR

- C.) HYGRISTOR
  - 1.) VIZ HYGRISTOR (PN-1286-162)

- D.) SMALL MUFFIN FAN
  - 1.) A.I.R. INC.

- E.) CABLES
  - 1.) 3 WIRE RIBBON w/ 3 Pin Mini-Din conn.

- F.) STRUCTURAL SUPPORT
  - 1.) CARBON TUBES 2ea. (20")

ANEMOMETER

1.) SUBASSEMBLIES REQUIRED

- A.) ANEMOMETER ENCODER UNIT w/ ENCODER BD.

B.) CABLES
    1.) 4 WIRE RIBBON w/ 4 Pin Mini-Din conn.

C.) PROPELLER
    1.) GILL PROPELLER
        a.) R.M. YOUNG INC.

D.) STRUCTURAL SUPPORT

    1.) CARBON TUBE (2ea.) 20"

TRANSPONDER

1.) STYROFOAM PACKAGE
    A.) CUSTOM BUILT

2.) SUBASSEMBLIES REQUIRED

    A.) TRANSPONDER
        1.) TERRA MOD. TRT-250
        2.) TERRA MOD. AT 3000 (ALTITUDE DIGITIZER)
        3.) TERRA MOD. TSO C74C (ANTENNA)

    B.) BATTERIES
        1.)ALTUS "D" SIZE (4ea.)

APPENDIX D

PHASE III PROGRAMS

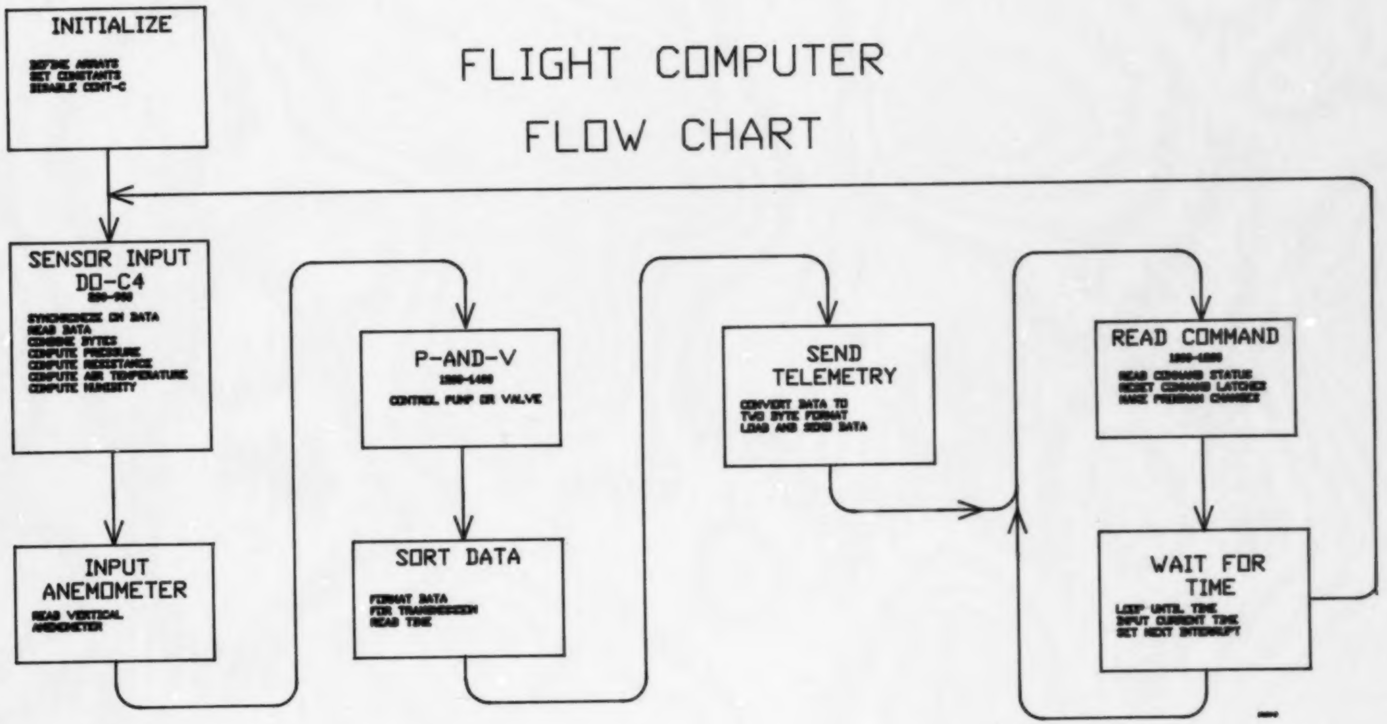
1. Flight control program flow chart........................94

2. Onboard flight control program "FLY 022".................95

3. Command and data reception PC program "GROUND"..........101

4. Command Encoder 8052AH Program "DO-COM".................106

FLIGHT COMPUTER
FLOW CHART


INITIALIZE
DEFINE ARRAYS
SET CONSTANTS
DISABLE CONT-C
SENSOR INPUT
DO-C4
SYNCHRONIZE ON DATA
READ DATA
COMBINE BYTES
COMPUTE PRESSURE
COMPUTE RESISTANCE
COMPUTE AIR TEMPERATURE
COMPUTE HUMIDITY
INPUT
ANEMOMETER
READ VERTICAL
ANEMOMETER
P-AND-V
CONTROL PUMP OR VALVE
SORT DATA
FORMAT DATA
FOR TRANSMISSION
READ TIME
SEND
TELEMETRY
CONVERT DATA TO
TWO BYTE FORMAT
LOAD AND SEND DATA
READ COMMAND
READ COMMAND STATUS
RESET COMMAND LATCHES
MAKE PROGRAM CHANGES
WAIT FOR
TIME
LOOP UNTIL TIME
INPUT CURRENT TIME
SET NEXT INTERRUPT

```
LIST
10       REM*****FLY0222***
15       REM ***22 FEB 88***
21       REM ** INITIALIZE UART **
22       FOR N=1 TO 3 : XBY(6001H)=0 :  NEXT N
23      XBY(6001H)=40H : XBY(6001H)=06FH
24      XBY(6001H)=10H
26       REM *** INITIALIZE SYSTEM ***
30      K1=6 : K2=840 : K3=15 : K4=1000
40      V1=0 : V2=0 : V7=0
50       DIM R(160) :  DIM W(9)
60      TIME=0 :  CLOCK 1
70      J1=0 : S1=10 : F2=-1
80      P1=900 : T2=15 : Z=4000
81      T1=18 : H=22 : T8=91
82      M4=10000
85       ONERR 1020
90       GOTO 1000
100      REM *** READ DATA FROM SELECTED PORT THRU UART ***
110      CALL 0AEFAH
135     A=3100H
140      FOR N=1 TO 160
145     R(N)=XBY(A)
146     A=A+1
150      NEXT N
190      RETURN
200     Q=2 :  GOSUB 5000
210      GOSUB 100
212      GOSUB 680
230     Q=1 :  GOSUB 5000
240      GOSUB 5180
250      GOSUB 5670
252      RETURN
260      REM *** SENSOR #2 ***
270     Q=4 :  GOSUB 5000
280      GOSUB 100
282      GOSUB 680
290     Q=1 :  GOSUB 5000
300      GOSUB 5180
310      GOSUB 6200
320      RETURN
600      REM ** TIME LOOP **
610      REM ** SPACE FOR MULTIPLE TIME EVENTS **
620      ONTIME TIME+1.5,660
630     F1=0
640      IF F1=0 THEN  GOTO 640
650      GOTO 680
660     F1=1
670      RETI
680      REM ** DECODE COMMANDS **
690      PRINT
700      GOSUB 3500
710      IF S1=0 THEN  GOTO 750
720      GOSUB 3900
725      IF S1=1 THEN  GOTO 740
730      GOSUB 760
740     S1=0
750      GOTO 830
760      REM *** DISPLAY STATE ***
770      PRINT K1,K2,K3,K4
780      PRINT P1,T2,Z
```

```
790    FOR N=1 TO 6
800   W(N)=0
810    NEXT N
820    RETURN
830    REM ** READ ANEMOMETER **
840    GOSUB 2600
850    PRINT Z
860    REM ** DO CONTROL **
870    GOSUB 2000
880    PRINT V1,V2
890    RETURN
1000   REM *** MAIN CONTROL PROGRAM
1010  F6=0
1020   GOSUB 600
1025  F6=F6+1
1030   IF F6=9 GOSUB 200
1040   IF F6=10 GOSUB 260
1050   IF F6=11 GOTO 1080
1060   GOTO 1020
1080   GOSUB 2400
1090   GOTO 1000
2000   REM   ** CONTROL **
2010   IF K1=1 THEN  GOTO 2080
2020   IF K1=2 THEN  GOTO 2120
2030   IF K1=3 THEN  GOTO 2160
2040   IF K1=4 THEN  GOTO 2190
2050   IF K1=5 THEN  GOTO 2200
2055   IF K1=6 THEN  GOTO 2180
2060   GOTO 2080
2070   REM  CONTROL ON PRESSURE
2080   IF P1>K2+2 THEN  GOTO 2190
2090   IF P1<K2-2 THEN  GOTO 2200
2100   GOTO 2180
2110   REM  CONTROL ON P TEMPERATURE
2120   IF T2<K3-0.1 THEN  GOTO 2190
2130   IF T2>K3+0.1 THEN  GOTO 2200
2140   GOTO 2180
2150   REM  CONTROL ON ALTIMITER
2160   IF Z>K4+500 THEN  GOTO 2190
2170   IF Z<K4-500 THEN  GOTO 2200
2180  A=0 :  GOTO 2210
2190  A=4 : V1=V1+1 :  GOTO 2210
2200  A=8 : V2=V2+1
2210  PORT1=148 : PORT1=20
2220  PORT1=A+16 : PORT1=144+A
2230  PORT1=255
2240   RETURN
2400   REM       ** SEND **
2410  R(1)=TIME : R(2)=P1*10 : R(3)=(T1+100)*10
2420  R(4)=H : R(5)=(T2+100)*10 : R(6)=P2*10
2430  R(7)=Z : R(8)=V2 : R(9)=V1
2440   IF K1=3 THEN R(10)=K4
2445   IF K1=2 THEN R(10)=(K3+100)*10
2450   IF K1=1 THEN R(10)=K2*10
2455   IF K1>3 THEN R(10)=0
2460  R(11)=K1 : R(12)=(T3+100)*10 : R(13)=(T4+100)*10
2470   FOR N=14 TO 16 : R(N)=0 :  NEXT N
2480   REM          ** S-TEL **
2490  PORT1=255 : PORT1=160
2500   FOR N=1 TO 10 : A=SIN(N) :  NEXT N
2510  PORT1=255 :  BAUD 1200 : Q=48 :  PRINT #CHR(Q),
2520   FOR N=1 TO 16 : A=R(N)
2530   IF A<0 THEN A=A*(-1)
2535  B=INT(A/256) : C=INT(A-256*B)
2540   PRINT #CHR(B), :  PRINT #CHR(C),
2550   NEXT N
```

```
2560   RETURN
2600   REM ** ANAMOMETER **
2602  A=1
2604   GOSUB 2740
2605  A=3
2610   GOSUB 2740
2620  A=0
2630   GOSUB 2740
2640  B=0
2650   GOSUB 2820
2660  A=1
2670   GOSUB 2740
2680   GOSUB 2820
2690   IF Z1-B>2000 THEN Z2=Z2+1
2700   IF Z1-B<-2000 THEN Z2=Z2-1
2710  Z1=B
2720  Z=B+Z2*4096
2722  A=0
2724   GOSUB 2740
2730   RETURN
2740   REM   SUB WRITE PORT
2750  P=6
2760  PORT1=128+P
2770  PORT1=P
2780  PORT1=A
2790  PORT1=128+A
2800  PORT1=255
2810   RETURN
2820   REM   SUB READ PORTS
2830  B=B*256
2840   FOR N=0 TO 1
2850  PORT1=128+N
2860  PORT1=N
2870  PORT1=15
2880  C=PORT1
2890  PORT1=255
2900  B=B+C*(1+15*N)
2910   NEXT N
2920   RETURN
3500   REM ** ROTATE ARRAY **
3510   FOR N=1 TO 8
3520  W(10-N)=W(9-N)
3530   NEXT N
3540   FOR N=2 TO 3
3550  PORT1=128+N
3560  PORT1=N
3570  PORT1=15
3580  X(N)=PORT1
3590  PORT1=255
3600   NEXT N
3610  W(1)=X(3)+2*X(2)
3615  Q=0 :  GOSUB 4300
3620   PRINT W(1),W(2),W(3),W(4),W(5),W(6)
3622  A=0
3624  B=0
3626   IF W(1)=W(2) THEN A=W(1)
3628   IF W(1)=W(3) THEN A=W(1)
3630   IF W(2)=W(3) THEN A=W(2)
3632   IF W(4)=W(5) THEN B=W(4)
3634   IF W(4)=W(6) THEN B=W(4)
3636   IF W(5)=W(6) THEN B=W(5)
3638   IF A=0 THEN 3700
3640   IF B=0 THEN 3700
3650   IF A=B THEN 3700
3660  S1=A-16+10*(B-16)
3690   PRINT S1
```

```
3700   RETURN
3900   REM *** READ COMMANDS ***
3910   IF S1=85 THEN  GOTO 4100
3920   IF S1=84 THEN  GOTO 4110
3930   IF S1=92 THEN  GOTO 4120
3940   IF S1=86 THEN  GOTO 4130
3950   IF S1=105 THEN  GOTO 4140
3960   IF S1=104 THEN  GOTO 4150
3970   IF S1=112 THEN  GOTO 4160
3980   IF S1=106 THEN  GOTO 4170
3990   IF S1=15 THEN  GOTO 4180
4000   IF S1=14 THEN  GOTO 4190
4010   IF S1=22 THEN  GOTO 4200
4020   IF S1=16 THEN  GOTO 4210
4025  S1=1
4030   RETURN
4100   PRINT "ON P TEMP" : K1=2
4102  K3=T2 :  RETURN
4110   PRINT "ON PRESSURE" : K1=1
4112  K2=P1 :  RETURN
4120   PRINT "ON ANEMOMETER" : K1=3
4122  K4=Z :  RETURN
4130   PRINT "DECREMENT"
4132   IF K1=1 THEN K2=K2-1
4134   IF K1=2 THEN K3=K3-1
4136   IF K1=3 THEN K4=K4-500
4138   RETURN
4140   PRINT "INCREMENT"
4142   IF K1=1 THEN K2=K2+1
4144   IF K1=2 THEN K3=K3+1
4146   IF K1=3 THEN K4=K4+500
4148   RETURN
4150   PRINT "RESET CUT DOWN" : Q=8
4152   GOSUB 4300
4154   RETURN
4160   PRINT "OPEN VALVE" : K1=4 :  RETURN
4170   PRINT "PUMP ON" : K1=5 :  RETURN
4180   PRINT "NO CONTROL " : K1=6 :  RETURN
4190   PRINT "SPAIR #4" :  RETURN
4200   PRINT "SPAIR #5" :  RETURN
4210   PRINT "CUT DOWN" : Q=4
4212   GOSUB 4300
4214   RETURN
4300   REM * CONTROL CUT DOWN *
4310  P=21
4320  PORT1=128+P
4330  PORT1=P
4340  PORT1=Q+16
4360  PORT1=255
4370   RETURN
5000   REM *** SELECT SENSOR ***
5010  DBY(38)=DBY(38).OR.1
5020  P=22
5030  PORT1=128+P
5040  PORT1=P
5050  PORT1=Q+16
5060  PORT1=255
5070   RETURN
5180   REM *** SORT ***
5200   REM *** ENABLE CTRL-C AND STOP
5210  DBY(38)=DBY(38).AND.0FEH
5220   DATA 85,85,85,85,60,149
5230  N=1 : B=1
5240  C1=0 : C2=0
5250   RESTORE
5260   READ A
```

```
5270   IF A=R(N) GOTO 5310
5280   IF N>160 THEN  GOTO 5660
5290  N=N+1
5300   GOTO 5270
5310  M=1
5320   READ A
5330  N=N+1
5340   IF A=R(N) GOTO 5360
5350   GOTO 5250
5360  M=M+1
5370   IF M=6 GOTO 5390
5380   GOTO 5320
5390   IF R(N+1)=12 THEN C1=N+3
5400   IF R(N+1)=15 THEN C2=N+3
5410  B=B+1
5420   IF B>5 THEN  GOTO 200
5422   IF C1=0 THEN  GOTO 5250
5424   IF C2=0 THEN  GOTO 5250
5430   FOR N=1 TO 4
5440  B=0
5450   IF C1=0 THEN  GOTO 5540
5460   FOR M=1 TO 3
5470  B=B*128+R(C1)
5480  C1=C1+1
5490   NEXT M
5510  B(N)=B
5520   NEXT N
5540   IF C2=0 THEN  GOTO 5660
5560   FOR N=1 TO 5
5570  B=0
5580   FOR M=1 TO 3
5590  B=B*128+R(C2)
5600  C2=C2+1
5610   NEXT M
5630  E(N)=B
5640   NEXT N
5650   PRINT
5660   RETURN
5670   REM *** SEN-1 ***
5680   REM *** SENSOR #100 ***
5690  A0=-0.4729250E+02 : A1=0.1189183E+04 : A2=0.4546314E+04
5700  A3=-0.5549027E+04 : A4=0.2979583E+04 : A5=-0.6375775E+03
5710  A8=-0.3378866E+04 : A9=0.1963101E+03 : A10=0.1702029E+04
5720  U1=(B(4)-B(1))/(B(3)-B(1))
5730  U2=(B(2)-B(1))/(B(3)-B(1))
5740  D1=A0+A1*U1+A2*U1**2+A3*U1**3+A4*U1**4+A5*U1**5
5750  D2=A8*U1*U2+A9*U2*U1**2+A10*U1*U2**2
5760  P=D1+D2
5770   PRINT P
5780  M1=(E(2)*1010000-E(1)*10000)/(E(1)-E(2))
5790  M2=(E(3)*(1000000+M1)-E(1)*M1)/(E(1)-E(3))
5800  M3=(E(4)*(1000000+M1)-E(1)*M1)/(E(1)-E(4))
5810   PRINT M1,M2,M3
5820   REM ADD-TO
5830  R1=14000
5840  L1=LOG(M2/R1) : L2=L1*L1 : L3=L2*L1
5850  T5=1/(.0032987+L1*4.7764E-04+L2*3.0029E-06+L3*1.5108E-06)
5860   PRINT "AIR TEMP =",T5
5870  T1=T5-273.15
5880   PRINT "T1=",T1
5890   REM         ** COMPUTE P-TEMP **
5900  T2=T5*(1000/P)**.286
5905  T2=T2-273.15
5910   PRINT "T2=",T2
5920   REM      ** COM-HUMI **
5930  R3=10000
```

```
5940   IF M2>R3 THEN  GOTO 5970
5950  C(0)=.9243 : C(1)=.003059 : C(2)=-1.188E-06 : C(3)=0
5960   GOTO 5990
5970  C(0)=.7885 : C(1)=9.286001E-03
5980  C(2)=-2.462E-05 : C(3)=-3.368E-07
5990  F1=C(0) : T4=T1
6000   FOR N=1 TO 3 : F1=F1+C(N)*T4 : T4=T4*T1 :  NEXT N
6010  F2=F1*LOG(M2/R3)
6020   IF F2>=-.2 THEN  GOTO 6060
6030  D(0)=-2.44 : D(1)=-7.37 : D(2)=-99.8
6040  D(3)=-251.4 : D(4)=-211 : A=0
6050   GOTO 6080
6060  D(0)=1 : D(1)=.729 : D(2)=-.0558
6070  D(3)=.00748 : D(4)=.0101 : A=102
6080  H1=D(0) : F3=F2
6090   FOR N=1 TO 4 : H1=H1+D(N)*F3 : F3=F3*F2 :  NEXT N
6100  H=A-69/H1 : P1=P : T9=1
6110   PRINT "HUMIDITY=",H
6120   RETURN
6200   REM *** SEN-2 ***
6210   REM ***SENSOR #122 ***
6220  A0=0.1252423E+04 : A1=-0.7693370E+04 : A2=0.4776503E+05
6230  A3=-0.8273214E+05 : A4=0.6963493E+05 : A5=-0.2333843E+05
6240  A8=-0.1086999E+05 : A9=0.5720530E+03 : A10=0.6984568E+04
6250  U1=(B(4)-B(1))/(B(3)-B(1))
6260  U2=(B(2)-B(1))/(B(3)-B(1))
6270  D1=A0+A1*U1+A2*U1**2+A3*U1**3+A4*U1**4+A5*U1**5
6280  D2=A8*U1*U2+A9*U2*U1**2+A10*U1*U2**2
6290  P=D1+D2 : P2=P
6300   PRINT P
6310  M1=(E(2)*1010000-E(1)*10000)/(E(1)-E(2))
6320  M2=(E(3)*(1000000+M1)-E(1)*M1)/(E(1)-E(3))
6330  M3=(E(4)*(1000000+M1)-E(1)*M1)/(E(1)-E(4))
6340   PRINT M1,M2,M3
6350   REM ADD-TO
6360  R1=14000
6370  L1=LOG(M2/R1) : L2=L1*L1 : L3=L2*L1
6380  T5=1/(.0032987+L1*4.7764E-04+L2*3.0029E-06+L3*1.5108E-06)
6390   PRINT "GAS TEMP 1=",T5
6400  T3=T5-273.15
6410   PRINT "T3=",T3
6430  L1=LOG(M2/R1) : L2=L1*L1 : L3=L2*L1
6440  T5=1/(.0032987+L1*4.7764E-04+L2*3.0029E-06+L3*1.5108E-06)
6450   PRINT "GAS TEMP 2=",T5
6460  T4=T5-273.15
6470   PRINT "T4=",T4
6480   RETURN

READY
>ROM

READY
```

```
LIST
10 REM   *** GROUND **
20 REM   ***** PROGRAM FOR SENDING AND RECEIVING FROM THE BALLOON *****
30 OPEN "COM1:300,N,8,1" AS #2
40 OPEN "KYBD:" FOR INPUT AS #3
50 COLOR 2,0
60 INPUT "INPUT CUTDOWN TIMEOUT SETTING (MIN)";TCUT
70 PRINT
80 PRINT " PROGRAM DOES NOT (REPEAT, DOES NOT) SEND"
90 PRINT " AUTOMATIC RESET CUTDOWN COMMANDS.  TO"
100 PRINT " ACTIVATE SUCH, TAKE 'REM' OFF 2310"
110 PRINT
120 INPUT "INPUT DISK DATA STORAGE FILENAME";FF$
130 OPEN FF$ FOR APPEND AS #4
140 DIM R(16),RR$(16)
150 REM *** COMMENTS *************************************
160 REM DD$   = DATE
170 REM TT$   = TIME (GENERATED BY PROGRAM GROUND DURING STORAGE)
180 REM SEN$  = BALLOON ID
190 REM Q$    = CONTROL PROGRAM COMMENT
200 REM R(1)  = TIME (MINUTES, GENERATED BY BALLOON PROCESSOR)
210 REM R(2)  = PRESSURE (MB)
220 REM R(3)  = AMBIENT AIR TEMPERATURE (C)
230 REM R(4)  = RELATIVE HUMIDITY (PERCENT)
240 REM R(5)  = AMBIENT POTENTIAL TEMPERATURE (CELCIUS)
250 REM R(6)  = INTERNAL PRESSURE (MB)
260 REM R(7)  = ANEMOMETER COUNT (200 IS ONE REVOLUTION)
270 REM R(8)  = NUMBER OF UPDATE INTERVALS WE HAVE BEEN VALVING
280 REM R(9)  = NUMBER OF UPDATE INTERVALS WE HAVE BEEN PUMPING
290 REM R(10) = 'TARGET' VALUE WE ARE CONTROLLING TOWARDS
300 REM R(11) = CONTROL PROGRAM KEY
310 REM         1 - CONSTANT PRESSURE
320 REM         2 - CONSTANT POTENTIAL TEMPERATURE
330 REM         3 - ZERO VERTICAL VELOCITY
340 REM R(12) = INTERNAL TEMPERATURE #1 (C)
350 REM R(13) = INTERNAL TEMPERATURE #2 (C)
360 REM R(14) = AVAILABLE
370 TLEFT = 0
380 REM *** DATA STATEMENTS ****************************
390 RR$(1)  = "TIME(MIN)           "
400 RR$(2)  = "PRESSURE(MB)        "
410 RR$(3)  = "TEMPERATURE(C)      "
420 RR$(4)  = "HUMIDITY(%)         "
430 RR$(5)  = "POT. TEMP. (C)      "
440 RR$(6)  = "INTERNAL PRESS. (MB)"
450 RR$(7)  = "ANEM. COUNT(200/REV)"
460 RR$(8)  = "INTERVALS PUMPING   "
470 RR$(9)  = "INTERVALS VALVING   "
480 RR$(10) = "TARGET CONTROL VALUE"
490 RR$(11) = "CONTROL PROG. KEY   "
500 RR$(12) = "INTERNAL TEMP #1 (C)"
510 RR$(13) = "INTERNAL TEMP #2 (C)"
520 REM *** KEY ASSIGNMENTS ****************************
530 KEY 1,"ON P-TEMP"
540 ON KEY(1) GOSUB 910
550 KEY(1) ON
560 KEY 2,"ON PRESSURE"
570 ON KEY(2) GOSUB 950
580 KEY(2) ON
590 KEY 3,"ON-ANNA"
600 ON KEY(3) GOSUB 990
610 KEY(3) ON
```

```
620 KEY 4,"DECREMENT"
630 ON KEY(4) GOSUB 1040
640 KEY(4) ON
650 KEY 5,"INCREMENT"
660 ON KEY(5) GOSUB 1080
670 KEY(5) ON
680 KEY 6,"RESET-CDT"
690 ON KEY(6) GOSUB 1120
700 KEY(6) ON
710 KEY 7,"PUMP"
720 ON KEY(7) GOSUB 1170
730 KEY(7) ON
740 KEY 8,"VALVE"
750 ON KEY(8) GOSUB 1210
760 KEY(8) ON
770 KEY 9,"DORMANT"
780 ON KEY(9) GOSUB 1250
790 KEY(9) ON
800 KEY 10,"RESERVE-2"
810 ON KEY(10) GOSUB 1290
820 KEY(10) ON
830 KEY 11,"TERMINATE"
840 ON KEY(11) GOSUB 1330
850 KEY(11) ON
860 KEY 12,"CUTDOWN"
870 ON KEY(12) GOSUB 1370
880 KEY(12) ON
890 GOTO 1550
900 REM **** KY SET *******************************************
910 KY=1
920 PRINT
930 PRINT DATE$,TIME$," SEND P-TEMP. CONTROL"
940 RETURN
950 KY=2
960 PRINT
970 PRINT DATE$,TIME$," SEND PRESSURE CONTROL"
980 RETURN
990 KY=3
1000 PRINT
1010 PRINT DATE$,TIME$," SEND ANEM. CONTROL"
1020 RETURN
1030 PRINT
1040 KY=4
1050 PRINT
1060 PRINT DATE$,TIME$," SEND DECREMENT "
1070 RETURN
1080 KY=5
1090 PRINT
1100 PRINT DATE$,TIME$," SEND INCREMENT "
1110 RETURN
1120 KY=6
1130 PRINT
1140 PRINT DATE$,TIME$," SEND RESET CUTDOWN"
1150 GOSUB 2730
1160 RETURN
1170 KY=7
1180 PRINT
1190 PRINT DATE$,TIME$," SEND OPEN VALVE "
1200 RETURN
1210 KY=8
```

```
1220 PRINT
1230 PRINT DATE$,TIME$," SEND TURN ON PUMPS"
1240 RETURN
1250 KY=9
1260 PRINT
1270 PRINT DATE$,TIME$," SEND DORMANT BALLOON CONTROLS"
1280 RETURN
1290 KY=10
1300 PRINT
1310 PRINT DATE$,TIME$," SEND RESERVE-2 CONTROL"
1320 RETURN
1330 KY=11
1340 PRINT
1350 PRINT DATE$,TIME$," SEND TERMINATE PROG. CONTROL"
1360 RETURN
1370 KY=12
1380 PRINT
1390 PRINT DATE$,TIME$," SEND CUTDOWN CONTROL"
1400 RETURN
1410 REM *** KY DIRECTORY ****************************************
1420 IF KY=1 GOTO 2380
1430 IF KY=2 GOTO 2400
1440 IF KY=3 GOTO 2420
1450 IF KY=4 GOTO 2440
1460 IF KY=5 GOTO 2460
1470 IF KY=6 GOTO 2480
1480 IF KY=7 GOTO 2500
1490 IF KY=8 GOTO 2520
1500 IF KY=9 GOTO 2540
1510 IF KY=10 GOTO 2560
1520 IF KY=11 GOTO 2580
1530 IF KY=12 GOTO 2650
1540 KY=0
1550 REM *******TERMINAL MODE ********************************
1560 PRINT
1570 KY=0
1580 IF KY>0 THEN GOTO 1410
1590 IF LOC(2)>0 THEN GOTO 1620
1600 IF LOC(3)>0 THEN GOTO 2340
1610 GOTO 1580
1620 A$=INPUT$(1,2)
1630 IF A$=CHR$(13) THEN GOTO 1660
1640 B$=B$+A$
1650 GOTO 1580
1660 IF LEN(B$)=75 THEN C$=LEFT$(B$,68)
1670 IF LEN(B$)=85 THEN GOTO 1700
1680 B$=""
1690 GOTO 1580
1700 C$=C$+MID$(B$,13,56)
1710 IF LEN(C$)<100 THEN GOTO 2320
1720 REM PRINT C$
1730 REM PRINT
1740 FOR M=1 TO 8
1750 FOR N=1 TO 2
1760 FOR S=1 TO 5
1770 K=M*14+1+(N-1)*6+S
1780 D$=MID$(C$,K,1)
1790 A=ASC(D$)
1800 IF A=32 THEN GOTO 1840
1810 IF A>64 THEN A=A-55
1820 IF A>47 THEN A=A-48
```

```
1830 B=16*B+A
1840 NEXT S
1850 REM PRINT B,
1860 R((M-1)*2+N)=B
1870 B=0
1880 NEXT N
1890 NEXT M
1900 REM PRINT
1910 R(1)=R(1)/60
1920 R(2)=R(2)/10
1930 R(3)=R(3)/10-100
1940 R(4)=R(4)
1950 R(5)=R(5)/10-100
1960 R(6)=R(6)/10
1970 IF R(11)=1 THEN Q$="CONTROL ON PRESSURE             "
1980 IF R(11)=1 THEN R(10)=R(10)/10
1990 IF R(11)=2 THEN Q$="CONTROL ON POTENTIAL TEMPERATURE"
2000 IF R(11)=2 THEN R(10)=R(10)/10-100
2010 IF R(11)=3 THEN Q$="CONTROL ON ANEMOMETER (200/REV) "
2020 IF R(11)=4 THEN Q$="OPEN VALVE                      "
2030 IF R(11)=5 THEN Q$="TURN ON PUMPS                   "
2040 IF R(11)=6 THEN Q$="TURN OFF PUMPS/CLOSE VALVE      "
2050 R(12) = R(12)/10-100
2060 R(13) = R(13)/10-100
2070 CC$=LEFT$(C$,12)
2080 DUM1$=DATE$
2090 DUM2$=TIME$
2100 GOSUB 2790
2110 PRINT
2120 PRINT DUM1$,DUM2$,RIGHT$(CC$,6)
2130 PRINT "REMAINING CUT-DOWN TIME (MIN) ",TLEFT
2140 PRINT Q$
2150 PRINT RR$(11),R(11)
2160 PRINT RR$(10),R(10)
2170 PRINT RR$(1),R(1)
2180 PRINT RR$(2),R(2)
2190 PRINT RR$(3),R(3)
2200 PRINT RR$(4),R(4)
2210 PRINT RR$(5),R(5)
2220 PRINT RR$(7),R(7)
2230 PRINT RR$(8),R(8)
2240 PRINT RR$(9),R(9)
2250 PRINT RR$(6),R(6)
2260 PRINT RR$(12),R(12)
2270 PRINT RR$(13),R(13)
2280 WRITE #4, DATE$,TIME$,RIGHT$(CC$,6),Q$
2290 WRITE #4, R(1),R(2),R(3),R(4),R(5),R(6),R(7)
2300 WRITE #4, R(8),R(9),R(10),R(11),R(12),R(13)
2310 REM IF TLEFT<1 THEN GOSUB 1070
2320 B$=""
2330 GOTO 1580
2340 A$=INPUT$(1,3)
2350 PRINT#2,A$;
2360 GOTO 1580
2370 REM ***** COMMAND STRINGS ******
2380 PRINT#2,"SEND COMMAND #50"
2390 GOTO 1550
2400 PRINT#2,"SEND COMMAND #52"
2410 GOTO 1550
2420 PRINT#2,"SEND COMMAND #53"
2430 GOTO 1550
```

```
2440 PRINT#2,"SEND COMMAND #54"
2450 GOTO 1550
2460 PRINT#2,"SEND COMMAND #60"
2470 GOTO 1550
2480 PRINT#2,"SEND COMMAND #62"
2490 GOTO 1550
2500 PRINT#2,"SEND COMMAND #63"
2510 GOTO 1550
2520 PRINT#2,"SEND COMMAND #64"
2530 GOTO 1550
2540 PRINT#2,"SEND COMMAND #70"
2550 GUTO 1550
2560 PRINT#2,"SEND COMMAND #72"
2570 GOTO 1550
2580 PRINT " YOU ARE NOW ABOUT TO KILL"
2590 PRINT " THIS PROGRAM RUN, CLOSE FILES ETC."
2600 PRINT " DO YOU REALLY WNAT TO DO THIS?"
2610 INPUT " ANSWER YES TO TERMINATE PROGRAM    ",A$
2620 IF A$="YES" THEN 2710
2630 PRINT " PROGRAM WILL CONTINUE"
2640 GOTO 1550
2650 INPUT "      ENTER   CUT DOWN     ",A$
2660 IF A$="CUT DOWN" THEN 2690
2670 PRINT "TRY AGAIN"
2680 GOTO 1550
2690 PRINT#2,"SEND COMMAND #74"
2700 GOTO 1550
2710 CLOSE
2720 END
2730 DUM$ = DATE$
2740 TSTART = VAL(MID$(DUM$,4,2))*24*60
2750 DUM$= TIME$
2760 TSTART=TSTART+VAL(RIGHT$(DUM$,2))/60+VAL(LEFT$(DUM$,2))*60
2770 TSTART= TSTART + VAL(MID$(DUM$,4,2))
2780 RETURN
2790 TNOW= VAL(MID$(DUM1$,4,2))*24*60
2800 TNOW=TNOW+VAL(RIGHT$(DUM2$,2))/60+VAL(LEFT$(DUM2$,2))*60
2810 TNOW=TNOW+VAL(MID$(DUM2$,4,2))
2820 TLEFT = TCUT-(TNOW-TSTART)
2830 RETURN
0
```

```
LIST
10       REM    **** DO-COM ****
20       STRING 500,20
30      $(2)="SEND COMMAND #"
40      F1=0
50       CLOCK 0
60       CLEAR I
70       INPUT "ENTER COMMAND  ",$(1)
80       FOR I=1 TO 14
90       IF ASC($(1),I)=ASC($(2),I) THEN  NEXT I ELSE 120
110      GOTO 140
120      PRINT "NOT A COMMAND"
130      GOTO 40
140     A=ASC($(1),15)-48
150     B=ASC($(1),16)-48
160      IF A>8 THEN 120
170      IF B>8 THEN 120
180      IF A=1 THEN 120
190      IF B=1 THEN 120
200      GOTO 330
210     PORT1=Q+16
220     PORT1=Q
230     TIME=0
240      CLOCK 1
250      ONTIME 20,300
260     F1=0
270      IF F1=0 THEN 270
280      RETURN
290      GOTO 40
300     PORT1=16
310     F1=1
320      RETI
330     Q=A
340      GOSUB 210
350     Q=B
360      GOSUB 210
370      GOTO 40
380      END

READY
```

APPENDIX E

ARGOS INFORMATION

1. Argos PTT program..108

2. Argos data format/structure..............................109

3. Tracer system Argos data frame...........................110

4. Sample of satellite-relayed data from the Tracer........111

ARGOS TRANSMITTER PROGRAM (PTT)

STORE DATA IN M ARRAY

```
10 DIM M(32)
20 FOR N=1 TO 32
30 M(N)=N+50
40 NEXT N
```

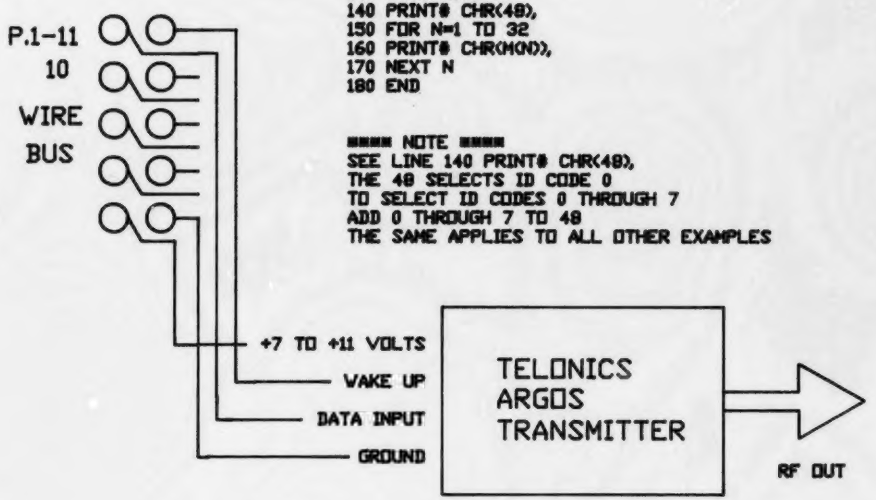
ACTIVATE WAKE UP

```
50 REM WAKE UP
60 PORT1=255
70 PORT1=160 ;chip select 2
80 FOR N=1 TO 10
90 A=SIN(N)
100 NEXT N
110 PORT1=255
```

LOAD DATA BUFFER 1 AND TRANSMIT

```
120 REM LOAD DATA
130 BAUD 1200
140 PRINT# CHR(48),
150 FOR N=1 TO 32
160 PRINT# CHR(M(N)),
170 NEXT N
180 END
```

```
**** NOTE ****
SEE LINE 140 PRINT# CHR(48),
THE 48 SELECTS ID CODE 0
TO SELECT ID CODES 0 THROUGH 7
ADD 0 THROUGH 7 TO 48
THE SAME APPLIES TO ALL OTHER EXAMPLES
```



LOAD DATA IN BUFFER 2 AND TRANSMIT

```
120 REM LOAD DATA
130 BAUD 1200
140 PRINT# CHR(64),
150 FOR N=1 TO 32
160 PRINT# CHR(M(N)),
170 NEXT N
180 END
```

LOAD DATA IN BUFFER 1 NO TRANSMIT

```
120 REM LOAD DATA
130 BAUD 1200
140 PRINT# CHR(16),
150 FOR N=1 TO 32
160 PRINT# CHR(M(N)),
170 NEXT N
180 END
```

LOAD DATA IN BUFFER 2 NO TRANSMIT

```
120 REM LOAD DATA
130 BAUD 1200
140 PRINT CHR(32),
150 FOR N=1 TO 32
160 PRINT# CHR(M(N)),
170 NEXT N
180 END
```

TRANSMIT DATA FROM BUFFER 1

```
120 REM TRANSMIT DATA
130 BAUD 1200
140 PRINT# CHR(80),
150 END
```

TRANSMIT DATA FROM BUFFER 2

```
120 REM TRANSMIT DATA
130 BAUD 1200
140 PRINT# CHR(96),
150 END
```

ARGOS DATA FORMAT/STRUCTURE

MESSAGE FORMAT AND STRUCTURE of the ARGOS
satellite uplink specification

```
Bits:(11111111 11111110 00101111 nnnpiiii iiiiiiii iieeeeee)+{4 to 32}
             15           8    1  3 1       14         6     { BYTES }

              B           F    I  N E        I         I          D
              I           O    N  U V        D         D          A
              T           R    I  M E                             T
                          M    T  B N        N         N          A
              S           A    I  E          U         U
              Y           T    A  R P        M         M
              N                L    A        B         B
              C           S    I  O R        E         E
                          Y    Z  F I        R         R
                          N    A    T
                          C    T  G Y                  E
                               I  R                    C
                               O  O O                  C
                               N  U N
                                  P                    C
                                  S G                  O
                                    R                  D
                                    O                  E
                                    U
                                    P
                                    S
```

NOTE: one "GROUP" = one "ARGOS WORD" = four (4) data bytes.

TRACER BALLOON: ARGOS DATA FRAME ASSIGNMENT

A typical data frame transmitted by the Tracer balloon might be:

```
F64CBA    0D B6 20 56  0B 58 01 92  1B F9 01 8B  03 48 00 0B
01 FF 20 5E  01 1C 00 01  00 00 00 00  00 00 00 00
```

These data, excepting the identification number, are hexadecimal-encoded sensor data.

Data word no.	Value in example	Assignment
1	F64CBA	Identification number
2,3	0D,B6	Elapsed time since launch (sec.)
4,5	20,56	Pressure (mb*10)
6,7	0B,58	Air temp. (deg. Kelvin*10)
8,9	01,92	Humidity (sensor resistance, ohms*10)
10,11	1B,F9	Potential temp. (deg. Kelvin*10)
12,13	01,8B	Strain (ohms/100))
14,15	03,48	Vertical anemom. (revolutions*50)
16,17	00,0B	Count of pump cycles
18,19	01,FF	Count of valve cycles
20,21	20,5E	Current control value
22,23	01,1C	Control code
24,25	00,01	Last command code
26 to 33	All 00	Not assigned

Control Codes:
1= Pressure
2= Potential temp.
3= Vertical anem. count
4= Pump only

Last Command Codes:
128= Control on pressure
64= Control on potential temp
32= Control on vert. anem. count
16= Increment current parameter
8= Decrement current parameter
4= Pump only
2= Reset cutdown timer
1= Cut down command .

```
 Telonics, Inc.   L O C A L   U S E R   T E R M I N A L   18 Aug 1987 12:02.
        Pass 72251450 Detailed Report for User:DAVE      Category:SANDIA
===========================================================================

06450 87 225 14:50z   34.902N  105.58 0984 0498 0061 05 03 000 0.0 10  -328.4
    06450 225 14:55:04.68  8207.8 -132.8 07 ----  017 082 082 111 004 133 000 054
                                                  004 001 221 218 068 205 000 000
                                                  000 000 000 000 000 006 004 213
                                                  098 024 000 000 004 000 000 000
    06450 225 14:55:53.11  7857.9 -131.3 00 -0.0  017 129 082 123 000 086 000 013
                                                  000 122 035 040 068 112 000 000
                                                  000 000 000 000 000 006 005 081
                                                  224 224 248 248 248 248 240 240
    06450 225 14:56:38.70  7280.7 -134.9 15 ----  017 177 031 074 004 158 000 053
                                                  004 169 035 059 069 233 000 000
                                                  000 000 000 000 000 006 004 217
                                                  199 020 000 000 000 000 000 000
    06450 225 15:02:47.59 -8556.7 -137.1 00 -0.1  019 034 031 084 004 158 000 052
                                                  004 170 036 235 120 028 000 000
                                                  000 000 000 000 000 006 004 213
                                                  015 172 000 000 000 000 000 000
    06450 225 15:03:44.82 -8930.8 -132.2 00  2.5  019 091 031 084 004 159 000 052
                                                  004 171 036 204 115 232 000 000
                                                  000 000 000 000 000 006 004 213
                                                  041 083 000 000 000 000 000 000
```

Sample of satellite-relayed data from Tracer Balloon. Output of Local User Terminal Courtesy of D. Beatty, Telonics, Inc.

APPENDIX F

REVISED LAUNCH PROCEDURES AND CHECKLISTS

1. Launch procedure..113

2. Chase vehicle/chase aircraft checklist..................115

3. Recovery procedure......................................116

LAUNCH PROCEDURE (REVISED 3/88)

BRIEFINGS AND NOTIFICATIONS

- Launch Director (LD), hold crew briefing day before to assign roles.
- On morning of flight, call Weather Service for morning wind profile and surface wind from Clines Corners (243-1453) available by 6:15-6:30 am.
- Notify FAA
    - o In all cases notify Flight Service Station: 243-7831 (Chuck Easton) at least 1 hour in advance of launch. Give FSS estimated time of launch, planned trajectory, planned max altitude, and planned duration.
    - o If flight planned above 1000 ft AGL, contact Air Route Traffic Control Center (821-3802) at least one hour in advance with the same information. Mention transponder code (0071). The contact there is Mark Kennedy. Can also get info from AARTCC during flight -- location of the transponder -- by calling 823-0571 (north specialty).
- If expect to go towards PECOS MOA, contact Maj. Zebenbergen at Cannon AFB (784-2276); Cannon Command Post (505) 784-2253; 126.2 MHz.
- On long flights, if approach Amarillo, contact Amarillo Approach control.

BEGIN PHYSICAL PREPS

- Have launch crew on scene at least 3 hours before planned launch.
- Synchronize watches.
- Distribute and check out radio transceivers; leave on.
- Put up small tethered balloon as wind indicator.
- Set up ground station (ARGOS, Command Transmitter, Computer).
- Set up ADAS and theodolite.
- Enter barometer and manometer readings into ground station program and ADAS. Log along with temperature.
- Launch and track an air sonde.
- Check out chase vehicle contents.
- Attach ribbon to cutdown timer switch (leave switch off).
- Attach vertical anemometer, external sensor and tracking beacon.
- Weigh off balloon. Suggest launch with at least 100 g of free lift.
- Deploy lead bricks (with carabiners) and tarp in launch area.
- Open hangar overhead door.
- Document operations from this point on with camera.
- Under the direction of the LD, bring the balloon out to the launch area with one person on each of the three handling lines.
- Attach handling lines to lead bricks w/carabiners.
- Hook up payload.
- Turn on Telonics tracking beacon.
- Hook up and turn on AIR sonde.
- Set (or check) time on dip switches and turn on cutdown package (but do not connect cutdown device yet).
- Put indicator LEDs in place on output of cutdown package.
- Turn on main package.

- Check out:
  - Beacon and receiver
  - Sonde and ADAS
  - Sensor package aspirator
  - Payload ARGOS telemetry link
  - Exercise command link by cycling through all commands:
    a. open valve
    b. pumps on
    c. dormant payload
    d. initiate pressure control
    e. increment control parameter (till pump turns on)
    f. decrement control parameter (till valve opens)
    g. initiate potential temperature control
    h. increment control parameter (till valve opens)
    i. decrement control parameter (till pump comes on)
    j. initiate relative vertical motion control
    k. rotate anemometer propeller to simulate air motion down relative to Tracer till pump comes on
    l. rotate anemometer in reverse direction until pump turns off and valve opens
    m. reset cutdown timer
    n. send cutdown command (check that indicater LEDs come on)
- Log surface pressure and temperature.
- Adjust free lift by metering air into or out of balloon if temperature or pressure has changed significantly since weighoff.
- Recycle payload (turn off and back on).
- Send reset cutdown timer.
- Connect cutdown leads to cutdown timer and remove ribbon.
- Hook up and turn on transponder and balancing balloon (if flight above 1000 ft AGL).
- Check code and function of transponder by use of check switch on panel.
- Send open valve, then dormant balloon commands; confirm operation.
- Choose point from which launch will take place.
- Under direction of LD, take balloon off of three point tether, and walk it over to the launch point with one man on each line, and one on the payload.
- Recheck ARGOS telemetry one last time.
- Prepare to track Tracer with optical theodolite,
- Release lines at direction of the LD.
- Valve if Tracer Balloon not rising fast enough.
- When Tracer nears desired altitude, put into desired control mode.
- Let altitude stabilize; fine tune with increment or decrement commands.
- Secure the area, putting bricks, tarps and other equipment in the hangar.
- Begin the chase operation at will.

EMERGENCY NUMBERS:	Medical, Fire or Police:		281-3302
	Power line problems:	PNM	848-4710
		Plains Elec	884-1881
	Telephone line problems:		765-6611

CHASE VEHICLE/CHASE AIRCRAFT CHECKLIST*

-Full gas tank (B)
-Briefcase with:
    Procedures (B)
    Logbook (B)
    Maps (aeronautical charts, road maps, topo maps) (B)
-Two way radio (on field test frequency) and external antenna (B)
-ADAS, recorder, and printer (B)
-Spare printer paper, tape cartridges (B)
-ADAS antenna w/tripod if not mounted externally (B)
-Command and Argos Data Reception System (B)
    PC (B)
    Argos receiver and decoder (B)
    Interface box (B)
    ICOM transmitter (B)
    Printer (B)
    Batteries and inverter (V)
    Command and Argos antennas with coax cable (B)
-35 mm camera w/spare film (B)
-Compass (V)
-Binoculars (B)
-Spare balloon top fitting cap (V)
-100 lb test cord for securing balloon on recovery (V)
-Lead bricks with handles and carabiners to hold balloon down in wind (V)
-Tarp to put balloon on during deflation (V)
-Tool kit with Allen wrench for baseplate (V)
-Shop Vac for rapid balloon deflation (V)
-Generator w/full gas tank to operate Shop Vac (V)

---

*V = Vehicle; A = Aircraft; B = Both.

RECOVERY PROCEDURE

- -If possible, chase vehicle should get close to Tracer before cutdown.
- -Send "cutdown" followed by "pumps on" if need to bring Tracer down rapidly.
- -If no hurry in bringing Tracer down, fly it down; turn pumps on to bring down to few hundred feet AGL; then send dormant balloon; send cutdown command and pumps on when favorable landing area presents itself.
- -Log times of commands and of touchdown.
- -If chase crew is in immediate area as Tracer comes down, try to snare handling lines as it descends; if balloon itself does not get swept into a fence, trees, or other obstruction, it will most likely be reusable.
- -IF THE BALLOON IS TANGLED OR OTHERWISE IN CONTACT WITH POWER LINES, UNDER NO CIRCUMSTANCES SHOULD ANYONE TOUCH THE BALLOON OR ITS HANDLING LINES. CALL THE POWER COMPANY FOR ASSISTANCE. POST A GUARD TO KEEP PEOPLE AWAY.
- -If there is no complication from power lines, attach handling lines to lead bricks with carabiners to secure the balloon.
- -Decide whether to deflate the balloon on the spot, or whether to walk it over to a road.
- -If the latter, close off the helium leak with the top fitting cap.
- -Turn off and remove main electronics package.
- -Turn off and remove transponder.
- -Remove other payload packages.
- -Balloon now ready to be walked over to a road, or deflated in place.
- -When balloon at spot chosen for deflation, lay out tarp.
- -Lay balloon on tarp and resecure with lead bricks.
- -Take off top and bottom fitting caps.
- -Use Shop Vac (if available) to speed deflation.
- -Take off bottom plate with valves and servo.
- -Wrap balloon in tarp to squeeze out air and helium; tie up when empty.
- -Stow balloon, fittings and payload packages in chase vehicle.
- -Note and log landmarks and distances to road intersections to identify landing point.
- -Contact FAA to inform them that the flight has concluded.

EMERGENCY NUMBERS:	Medical, Fire or Police:		281-3302
	Power line problems:	PNM	848-4710
		Plains Elec	884-1881
	Telephone line problems:		765-6611

APPENDIX G

DATA FROM TEST FLIGHTS

1. Argos data from flight 1..............................118

2. Notes on flight 1 Argos data..........................122

3. AIR sonde data from flight 1..........................123

4. Notes on flight 1 AIR sonde data......................130

5. Argos data from flight 2..............................131

6. Notes on flight 2 Argos data..........................133

7. AIR sonde data from flight 2..........................134

8. Notes on flight 2 AIR sonde data......................140

ARGOS DATA FROM FLIGHT 1

```
TURN OFF PUMPS/CLOSE VALVE
CONTROL PROG. KEY            6
TARGET CONTROL VALUE         0
TIME(MIN)                    29.41667
PRESSURE(MB)                 801.6
TEMPERATURE(C)               22.6
HUMIDITY(%)                  50
POT. TEMP. (C)               24.1
ANEM. COUNT(200/REV)         4373
INTERVALS PUMPING            0
INTERVALS VALVING            0
INTERNAL PRESS. (MB)         1269.6
INTERNAL TEMP #1 (C)         25.1
INTERNAL TEMP #2 (C)         262.9

08-13-1987    10:46:52       SEND OPEN VALVE


08-13-1987    10:47:15       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:48:28       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:49:05       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:49:12       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:49:17      F64CBA
REMAINING CUT-DOWN TIME (MIN)              26.13281
OPEN VALVE
CONTROL PROG. KEY            4
TARGET CONTROL VALUE         0
TIME(MIN)                    31.96667
PRESSURE(MB)                 783.1
TEMPERATURE(C)               25.1
HUMIDITY(%)                  49
POT. TEMP. (C)               26.9
ANEM. COUNT(200/REV)         274
INTERVALS PUMPING            0
INTERVALS VALVING            4
INTERNAL PRESS. (MB)         1245.1
INTERNAL TEMP #1 (C)         25.9
INTERNAL TEMP #2 (C)         4962.6

08-13-1987    10:49:28       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:50:42       SEND OPEN VALVE


08-13-1987    10:51:10       SEND OPEN VALVE


08-13-1987    10:51:27       SEND OPEN VALVE


08-13-1987    10:51:57      F64CBA
REMAINING CUT-DOWN TIME (MIN)              23.4668
TURN OFF PUMPS/CLOSE VALVE
CONTROL PROG. KEY            6
TARGET CONTROL VALUE         0
TIME(MIN)                    34.63334
PRESSURE(MB)                 2041.4
```

```
TEMPERATURE(C)               21.6
HUMIDITY(%)                  51
POT. TEMP. (C)               17.6
ANEM. COUNT(200/REV)         6188
INTERVALS PUMPING            0
INTERVALS VALVING            14
INTERNAL PRESS. (MB)         6126
INTERNAL TEMP #1 (C)         28.4
INTERNAL TEMP #2 (C)         3399.1

08-13-1987    10:52:15       SEND OPEN VALVE


08-13-1987    10:52:29       SEND OPEN VALVE


08-13-1987    10:52:48      F64CBA
REMAINING CUT-DOWN TIME (MIN)              22.61524
TURN OFF PUMPS/CLOSE VALVE
CONTROL PROG. KEY            6
TARGET CONTROL VALUE         0
TIME(MIN)                    35.48333
PRESSURE(MB)                 800
TEMPERATURE(C)               8.300003
HUMIDITY(%)                  51
POT. TEMP. (C)               22.5
ANEM. COUNT(200/REV)         13944
INTERVALS PUMPING            0
INTERVALS VALVING            14
INTERNAL PRESS. (MB)         1078.6
INTERNAL TEMP #1 (C)        -94.3
INTERNAL TEMP #2 (C)        -90.8

08-13-1987    10:52:57       SEND OPEN VALVE


08-13-1987    10:53:53      F64CBA
REMAINING CUT-DOWN TIME (MIN)              21.5332
OPEN VALVE
CONTROL PROG. KEY            4
TARGET CONTROL VALUE         0
TIME(MIN)                    36.55
PRESSURE(MB)                 800
TEMPERATURE(C)               20.9
HUMIDITY(%)                  51
POT. TEMP. (C)               22.5
ANEM. COUNT(200/REV)         26169
INTERVALS PUMPING            0
INTERVALS VALVING            23
INTERNAL PRESS. (MB)         1078.6
INTERNAL TEMP #1 (C)        -94.3
INTERNAL TEMP #2 (C)        -90.8

08-13-1987    10:54:40      F64CBA
REMAINING CUT-DOWN TIME (MIN)              20.75
OPEN VALVE
CONTROL PROG. KEY            4
TARGET CONTROL VALUE         0
TIME(MIN)                    37.35
PRESSURE(MB)                 797
TEMPERATURE(C)               20.2
HUMIDITY(%)                  52
POT. TEMP. (C)               21.6
ANEM. COUNT(200/REV)         27402
INTERVALS PUMPING            0
INTERVALS VALVING            35
```

```
INTERNAL PRESS. (MB)         818.5
INTERNAL TEMP #1 (C)         27.4
INTERNAL TEMP #2 (C)         5250.2

08-13-1987    10:55:30      F64CBA
REMAINING CUT-DOWN TIME (MIN)               19.91602
OPEN VALVE
CONTROL PROG. KEY            4
TARGET CONTROL VALUE         0
TIME(MIN)                    38.18334
PRESSURE(MB)                 1957.2
TEMPERATURE(C)               20
HUMIDITY(%)                  52
POT. TEMP. (C)               16.5
ANEM. COUNT(200/REV)         33587
INTERVALS PUMPING            0
INTERVALS VALVING            48
INTERNAL PRESS. (MB)         4893.4
INTERNAL TEMP #1 (C)         27.2
INTERNAL TEMP #2 (C)        -38.9

08-13-1987    10:56:17      F64CBA
REMAINING CUT-DOWN TIME (MIN)               19.13281
OPEN VALVE
CONTROL PROG. KEY            4
TARGET CONTROL VALUE         0
TIME(MIN)                    38.95
PRESSURE(MB)                 795.2
TEMPERATURE(C)               19.8
HUMIDITY(%)                  52
POT. TEMP. (C)               21.1
ANEM. COUNT(200/REV)         41134
INTERVALS PUMPING            0
INTERVALS VALVING            60
INTERNAL PRESS. (MB)         601.7
INTERNAL TEMP #1 (C)         27.1
INTERNAL TEMP #2 (C)         4480.5

08-13-1987    10:57:13       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:57:38      F64CBA
REMAINING CUT-DOWN TIME (MIN)               17.7832
OPEN VALVE
CONTROL PROG. KEY            4
TARGET CONTROL VALUE         0
TIME(MIN)                    40.31667
PRESSURE(MB)                 793.1
TEMPERATURE(C)               19.7
HUMIDITY(%)                  52
POT. TEMP. (C)               21.1
ANEM. COUNT(200/REV)         55820
INTERVALS PUMPING            0
INTERVALS VALVING            72
INTERNAL PRESS. (MB)         420
INTERNAL TEMP #1 (C)         131.9
INTERNAL TEMP #2 (C)         1628.6

08-13-1987    10:57:49       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:58:12       SEND DORMANT BALLOON CONTROLS


08-13-1987    10:58:27      F64CBA
REMAINING CUT-DOWN TIME (MIN)               16.9668
```

```
TURN OFF PUMPS/CLOSE VALVE
CONTROL PROG. KEY            6
TARGET CONTROL VALUE         0
TIME(MIN)                    41.13334
PRESSURE(MB)                 784.1
TEMPERATURE(C)               19.5
HUMIDITY(%)                  52
POT. TEMP. (C)               20.9
ANEM. COUNT(200/REV)         7298
INTERVALS PUMPING            0
INTERVALS VALVING            76
INTERNAL PRESS. (MB)         207.7
INTERNAL TEMP #1 (C)         26.9
INTERNAL TEMP #2 (C)         2556.4

08-13-1987    10:59:04       SEND DORMANT BALLOON CONTROLS


08-13-1987    11:00:32      F64CBA
REMAINING CUT-DOWN TIME (MIN)              14.88281
TURN OFF PUMPS/CLOSE VALVE
CONTROL PROG. KEY            6
TARGET CONTROL VALUE         0
TIME(MIN)                    43.21667
PRESSURE(MB)                 770.2
TEMPERATURE(C)               19.3
HUMIDITY(%)                  52
POT. TEMP. (C)               20.7
ANEM. COUNT(200/REV)         43778
INTERVALS PUMPING            0
INTERVALS VALVING            76
INTERNAL PRESS. (MB)         6476.3
INTERNAL TEMP #1 (C)         26.6
INTERNAL TEMP #2 (C)         1175.8

08-13-1987    11:01:44       SEND TURN ON PUMPS


08-13-1987    11:02:27       SEND TURN ON PUMPS


08-13-1987    11:03:08       SEND RESET CUTDOWN


08-13-1987    11:03:25       SEND PRESSURE CONTROL


08-13-1987    11:05:00       SEND PRESSURE CONTROL


08-13-1987    11:07:00       SEND PRESSURE CONTROL


08-13-1987    11:11:50       SEND PRESSURE CONTROL


08-13-1987    11:12:35       SEND PRESSURE CONTROL


08-13-1987    11:16:20       SEND PRESSURE CONTROL


08-13-1987    11:51:12       SEND DORMANT BALLOON CONTROLS


08-13-1987    11:51:26       SEND CUTDOWN CONTROL
```

NOTES ON FLIGHT 1 ARGOS DATA

- This flight took place before the flight computer was modified by installation of the USART, and before the control program included a machine language subroutine to read the sensors through the USART. Hence, sensor read errors are still present.

AIR SONDE DATA FROM FLIGHT 1

DATE	TMDAY	PR=MB	PHT=M	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AR=MS	AZ=DG	EL=DG
870813	104458	803.3	2.	20.70	13.77	71.3	15.32	270.0	0.00	-1.20	90.00	0.00
870813	104503	803.1	4.	20.56	12.54	65.6	13.89	270.0	0.00	0.51	90.00	0.00
870813	104508	789.2	155.	20.46	12.61	65.2	13.71	270.0	3039.56	31.33	90.00	0.00
870813	104513	803.2	4.	20.55	12.26	64.2	13.55	270.0	3039.56	-31.35	90.00	0.00
870813	104518	803.6	-1.	20.71	12.37	64.1	13.69	270.0	3039.56	-0.86	90.00	0.00
870813	104522	803.2	4.	20.83	12.48	64.2	13.82	90.0	3036.20	0.91	90.00	0.00
870813	104527	803.5	0.	20.73	12.60	65.2	13.97	90.0	3036.20	-0.77	90.00	0.00
870813	104532	803.9	-4.	20.54	12.65	66.3	14.04	90.0	3036.20	-0.81	90.00	0.00
870813	104537	802.8	8.	20.60	12.62	65.8	13.98	270.0	0.00	2.40	90.00	0.00
870813	104542	803.2	4.	20.85	12.57	64.6	13.92	270.0	0.00	-0.86	90.00	0.00
870813	104547	802.3	13.	20.86	12.68	65.0	14.04	270.0	0.00	1.89	90.00	0.00
870813	104551	803.5	0.	20.73	12.52	64.8	13.87	270.0	0.00	-2.62	90.00	0.00
870813	104556	803.0	5.	20.91	12.54	64.2	13.88	270.0	0.00	1.06	90.00	0.00
870813	104601	803.0	5.	20.95	12.57	64.2	13.93	270.0	0.00	-0.02	90.00	0.00
870813	104606	802.7	9.	20.81	12.52	64.5	13.86	270.0	0.00	0.72	90.00	0.00
870813	104611	803.0	6.	20.78	12.37	63.9	13.69	270.0	0.00	-0.55	90.00	0.00
870813	104616	804.0	-5.	20.67	12.36	64.3	13.69	270.0	0.00	-2.34	90.00	0.00
870813	104620	803.4	1.	20.70	12.31	63.9	13.62	270.0	0.00	1.32	90.00	0.00
870813	104625	803.6	-1.	20.53	12.34	64.7	13.65	270.0	0.00	-0.37	90.00	0.00
870813	104630	803.2	3.	20.55	12.40	64.9	13.72	270.0	0.00	0.73	90.00	0.00
870813	104635	803.6	-1.	20.59	12.36	64.6	13.68	270.0	0.00	-0.84	90.00	0.00
870813	104640	803.2	4.	20.60	12.37	64.6	13.69	270.0	0.00	1.02	90.00	0.00
870813	104644	816.7	-140.	20.53	12.09	64.4	13.59	270.0	0.00	-29.83	90.00	0.00
870813	104649	799.4	-140.	20.62	13.66	70.7	15.12	8888.9	8888.88	8888.88	90.00	0.00
870813	104654	817.0	-140.	20.37	11.78	63.5	13.21	8888.9	8888.88	8888.88	90.00	0.00
870813	104659	803.5	-0.	20.27	12.08	64.4	13.34	8888.9	8888.88	9.68	90.00	0.00
870813	104704	801.6	21.	20.51	12.08	63.3	13.30	270.0	0.00	4.24	90.00	0.00
870813	104709	800.8	29.	20.11	12.28	65.9	13.53	270.0	0.00	1.68	90.00	0.00
870813	104714	804.2	-7.	20.05	12.09	65.4	13.36	270.0	0.00	-7.38	90.11	0.00
870813	104718	803.0	6.	19.64	12.16	67.3	13.42	270.0	0.00	2.67	90.90	0.00
870813	104723	803.3	3.	19.89	12.02	65.6	13.25	270.0	0.00	-0.62	117.97	0.04
870813	104728	803.4	1.	20.22	12.08	64.6	13.33	270.0	0.00	-0.32	117.29	1.98
870813	104733	803.3	2.	20.06	12.19	65.8	13.46	270.0	0.00	0.18	117.79	2.05
870813	104738	803.4	1.	19.81	12.42	68.1	13.75	270.0	0.00	-0.17	117.79	2.05
870813	104743	804.0	-6.	19.53	12.63	70.5	14.01	270.0	0.00	-1.42	117.79	2.05
870813	104747	803.2	3.	19.49	12.68	70.9	14.05	270.0	0.00	1.89	117.79	2.09
870813	104752	803.8	-3.	19.45	12.53	70.2	13.89	270.0	0.00	-1.38	117.79	2.12
870813	104757	804.1	-7.	19.63	12.32	68.3	13.64	270.0	0.00	-0.74	117.79	2.09
870813	104802	803.2	3.	19.91	12.21	66.5	13.49	270.0	0.00	2.02	117.83	2.09
870813	104807	803.2	3.	20.12	12.20	65.6	13.48	270.0	0.00	-0.00	117.83	2.09
870813	104811	803.2	3.	20.05	12.28	66.3	13.58	270.0	0.00	-0.05	117.79	2.12
870813	104816	803.0	5.	20.05	12.18	65.8	13.45	270.0	0.00	0.53	117.79	2.12
870813	104821	804.1	-6.	20.10	12.15	65.5	13.43	270.0	0.00	-2.39	117.79	2.12
870813	104826	803.3	2.	20.27	12.30	65.6	13.60	270.0	0.00	1.74	117.79	2.16
870813	104831	802.5	10.	20.14	12.36	66.4	13.66	270.0	0.00	1.65	117.79	2.16
870813	104836	803.2	4.	20.12	12.23	65.8	13.52	270.0	0.00	-1.37	117.79	2.16
870813	104840	803.9	-4.	20.45	12.21	64.4	13.51	270.0	0.00	-1.69	117.79	2.16
870813	104845	803.4	1.	20.55	12.28	64.4	13.59	270.0	0.00	1.21	117.79	2.16
870813	104850	803.8	-3.	20.70	12.35	64.1	13.67	270.0	0.00	-0.87	117.79	2.16
870813	104855	803.1	5.	20.47	12.59	66.2	13.95	270.0	0.00	1.56	117.79	2.16
870813	104900	802.9	6.	20.33	12.60	66.8	13.96	270.0	0.00	0.26	117.79	2.16
870813	104905	802.7	9.	20.22	12.63	67.4	13.99	270.0	0.00	0.54	117.76	2.16
870813	104909	803.2	3.	20.36	12.51	66.2	13.85	270.0	0.00	-1.16	117.76	2.12
870813	104914	803.3	3.	20.59	12.45	65.1	13.79	270.0	0.00	-0.06	107.78	2.48
870813	104919	803.0	5.	20.67	12.39	64.4	13.71	270.0	0.00	0.52	100.55	5.11
870813	104924	802.9	7.	20.78	12.37	63.8	13.68	270.0	0.00	0.36	95.08	5.26

DATE	TMDAY	PR=MB	PHT=M	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AR=MS	AZ=DG	EL=DG
870813	104929	802.5	10.	21.00	12.31	62.6	13.60	270.0	0.00	0.70	91.33	6.98
870813	104934	802.3	13.	21.20	12.36	62.1	13.66	270.0	0.00	0.52	88.88	7.24
870813	104938	802.2	15.	21.28	12.48	62.4	13.80	270.0	0.00	0.35	87.16	6.88
870813	104943	802.1	15.	21.44	12.58	62.2	13.92	270.0	0.00	0.17	86.04	6.55
870813	104948	802.1	15.	21.07	12.80	64.8	14.18	270.0	0.00	-0.01	85.50	6.12
870813	104953	802.2	15.	20.97	12.77	65.1	14.15	270.0	0.00	-0.18	85.00	4.90
870813	104958	802.2	14.	21.14	12.61	63.6	13.95	270.0	0.00	-0.00	84.56	3.89
870813	105003	802.2	14.	21.32	12.54	62.6	13.88	270.0	0.00	-0.00	84.10	3.71
870813	105007	802.3	13.	21.01	12.70	64.6	14.07	270.0	0.00	-0.36	84.10	3.71
870813	105012	802.2	14.	20.79	12.74	65.6	14.12	270.0	0.00	0.34	84.06	3.71
870813	105017	802.2	14.	20.43	12.64	66.6	13.99	270.0	0.00	-0.18	84.06	3.71
870813	105022	802.2	14.	20.33	12.45	66.0	13.76	270.0	0.00	0.18	84.10	3.71
870813	105027	802.2	14.	20.42	12.32	64.9	13.61	270.0	0.00	-0.01	84.06	3.71
870813	105031	802.3	13.	20.17	12.20	65.3	13.46	270.0	0.00	-0.34	84.06	3.71
870813	105036	802.3	13.	20.17	12.11	64.8	13.35	270.0	0.00	0.00	84.10	3.71
870813	105041	802.4	12.	20.60	11.92	62.2	13.11	270.0	0.00	-0.17	84.10	3.60
870813	105046	802.4	12.	20.53	11.92	62.5	13.12	270.0	0.00	-0.01	83.84	3.56
870813	105051	802.4	12.	20.18	11.91	63.8	13.10	270.0	0.00	-0.01	83.81	3.56
870813	105056	802.8	8.	19.90	11.86	64.7	13.05	270.0	0.00	-0.86	83.84	3.56
870813	105100	802.6	10.	19.55	11.67	65.0	12.80	270.0	0.00	0.41	83.84	3.53
870813	105105	802.7	9.	19.48	11.62	65.0	12.74	270.0	0.00	-0.19	83.81	3.56
870813	105110	802.4	12.	19.40	11.58	65.1	12.68	270.0	0.00	0.68	83.84	3.56
870813	105115	802.3	13.	19.34	11.53	65.1	12.62	270.0	0.00	0.16	83.81	3.56
870813	105120	802.0	16.	19.30	11.50	65.1	12.57	270.0	0.00	0.69	83.84	3.56
870813	105125	802.2	14.	19.24	11.48	65.2	12.54	270.0	0.00	-0.52	83.81	3.60
870813	105129	802.0	16.	19.24	11.46	65.1	12.52	270.0	0.00	0.51	83.48	3.60
870813	105134	802.0	16.	19.24	11.45	65.0	12.50	270.0	0.00	0.00	83.23	3.67
870813	105139	802.2	14.	19.21	11.41	65.0	12.46	270.0	0.00	-0.35	83.23	3.71
870813	105144	802.3	13.	19.29	11.36	64.3	12.39	270.0	0.00	-0.36	83.23	3.71
870813	105149	802.6	9.	19.42	11.35	63.8	12.38	270.0	0.00	-0.70	83.27	3.67
870813	105154	802.7	8.	19.65	11.35	62.9	12.38	270.0	0.00	-0.17	83.27	3.71
870813	105158	88888888	88888888	19.91	88888888	88888888	88888888	88888888	88P88888	88888888	83.27	3.71
870813	105203	802.6	8.	20.26	11.35	60.6	12.38	270.0	0.00	8888.88	83.27	3.67
870813	105208	802.4	11.	20.31	11.56	61.4	12.65	270.0	0.00	0.21	83.27	3.67
870813	105213	802.4	12.	20.40	11.62	61.4	12.73	270.0	0.00	0.20	83.20	3.71
870813	105218	802.2	14.	19.93	11.73	63.8	12.87	270.0	0.00	0.36	83.20	3.74
870813	105222	801.9	18.	19.74	11.70	64.3	12.82	270.0	0.00	0.71	83.23	3.74
870813	105227	801.5	22.	19.78	11.60	63.6	12.68	270.0	0.00	0.88	83.23	3.74
870813	105232	801.3	23.	19.64	11.59	64.1	12.67	270.0	0.00	0.35	83.23	3.74
870813	105237	800.8	29.	19.77	11.57	63.5	12.63	263.2	31.86	1.05	83.23	3.74
870813	105242	800.9	28.	19.89	11.51	62.7	12.56	263.2	31.86	-0.15	83.23	3.74
870813	105247	800.4	33.	19.81	11.49	62.8	12.52	263.2	31.86	1.03	83.23	3.74
870813	105251	800.2	35.	19.91	11.47	62.4	12.50	263.2	6.71	0.55	83.23	3.74
870813	105256	799.8	40.	19.59	11.58	64.1	12.63	263.2	6.71	0.87	83.16	3.71
870813	105301	799.7	41.	19.35	11.57	65.1	12.62	263.2	6.71	0.18	82.98	3.78
870813	105306	799.7	41.	19.31	11.54	65.0	12.57	260.7	5.59	0.18	82.91	3.82
870813	105311	799.4	44.	19.20	11.50	65.2	12.52	260.7	5.59	0.52	82.98	3.82
870813	105316	799.3	45.	19.19	11.45	65.0	12.45	260.7	5.59	0.18	82.98	3.82
870813	105320	799.3	45.	19.25	11.41	64.5	12.40	352.9	0.03	0.00	82.94	3.82
870813	105325	799.3	46.	19.55	11.32	62.9	12.28	352.9	0.03	0.18	82.91	3.82
870813	105330	799.1	47.	19.74	11.35	62.2	12.31	352.9	0.03	0.35	82.91	3.82
870813	105335	799.1	47.	19.94	11.40	61.8	12.38	262.7	6.30	0.00	82.91	3.82
870813	105340	798.9	50.	19.74	11.50	63.1	12.51	262.7	6.30	0.52	82.33	3.85
870813	105345	798.9	49.	19.73	11.48	63.0	12.48	262.7	6.30	-0.17	82.19	3.82
870813	105349	799.0	48.	19.91	11.43	62.0	12.42	215.2	1.04	-0.17	82.04	3.74
870813	105354	799.1	47.	20.05	11.39	61.3	12.37	215.2	1.04	-0.17	81.86	3.71

DATE	TMDAY	PR=MB	PHT=M	DT=DC	MR=GM	RH=PC	DW=DC	DD=DG	DS=MS	AR=MS	AZ=DG	EL=DG
870813	105359	799.1	47.	20.16	11.41	61.0	12.39	215.2	1.04	0.00	81.68	3.64
870813	105404	798.9	49.	20.30	11.39	60.3	12.36	246.3	1.96	0.36	81.47	3.64
870813	105409	798.9	49.	20.38	11.46	60.4	12.45	246.3	1.96	0.00	81.32	3.64
870813	105414	798.9	50.	20.38	11.54	60.8	12.56	246.3	1.96	0.18	81.22	3.64
870813	105418	798.6	52.	20.49	11.59	60.6	12.62	119.3	0.43	0.53	81.18	3.67
870813	105423	798.6	52.	20.49	11.57	60.5	12.59	119.3	0.43	0.01	81.14	3.71
870813	105428	798.4	55.	20.38	11.63	61.2	12.67	119.3	0.43	0.53	81.07	3.74
870813	105433	798.3	56.	20.41	11.57	60.8	12.59	258.4	4.38	0.17	80.96	3.78
870813	105438	798.2	57.	20.51	11.62	60.7	12.65	258.4	4.38	0.19	80.86	3.82
870813	105442	797.9	60.	20.64	11.65	60.3	12.68	258.4	4.38	0.70	80.68	3.89
870813	105447	797.8	61.	20.53	11.64	60.7	12.67	253.9	3.73	0.19	80.53	3.96
870813	105452	797.6	64.	20.17	11.71	62.4	12.75	253.9	3.73	0.53	80.39	4.00
870813	105457	797.4	65.	19.96	11.71	63.2	12.75	253.9	3.73	0.36	80.28	4.07
870813	105502	797.1	69.	19.96	11.66	62.9	12.68	252.9	3.34	0.70	80.14	4.14
870813	105507	797.0	70.	20.18	11.55	61.4	12.53	252.9	3.34	0.37	79.99	4.25
870813	105511	796.8	72.	20.24	11.56	61.3	12.55	252.9	3.34	0.36	79.81	4.28
870813	105516	796.6	75.	20.24	11.61	61.5	12.61	243.4	2.16	0.53	79.60	4.36
870813	105521	796.3	78.	20.14	11.65	62.1	12.65	243.4	2.16	0.71	79.49	4.36
870813	105526	796.0	81.	19.94	11.68	63.0	12.69	243.4	2.16	0.53	79.20	4.46
870813	105531	795.8	83.	19.95	11.64	62.7	12.63	253.6	7.56	0.54	78.98	4.54
870813	105536	795.7	84.	19.98	11.53	62.0	12.49	253.6	7.56	0.18	78.77	4.57
870813	105540	795.5	87.	19.90	11.53	62.3	12.49	253.6	7.56	0.53	78.52	4.57
870813	105545	795.4	88.	19.78	11.61	63.2	12.59	148.4	0.98	0.19	78.26	4.57
870813	105550	795.3	88.	19.81	11.56	62.8	12.51	148.4	0.98	0.18	78.12	4.61
870813	105555	795.0	92.	19.84	11.60	62.9	12.56	148.4	0.98	0.69	77.90	4.68
870813	105600	794.7	95.	19.77	11.73	63.8	12.73	251.4	6.69	0.70	77.69	4.79
870813	105605	794.4	98.	19.91	11.75	63.4	12.75	251.4	6.69	0.54	77.51	4.82
870813	105609	794.2	100.	20.06	11.75	62.8	12.74	251.4	6.69	0.54	77.33	4.93
870813	105614	794.0	103.	19.97	11.80	63.3	12.80	224.6	1.50	0.54	77.11	5.00
870813	105619	793.5	108.	20.11	11.68	62.2	12.63	224.6	1.50	1.06	76.90	5.11
870813	105624	793.2	112.	20.13	11.70	62.2	12.66	224.6	1.50	0.72	76.75	5.18
870813	105629	792.8	116.	20.09	11.76	62.6	12.73	247.4	4.81	0.89	76.57	5.29
870813	105633	792.5	119.	19.96	11.78	63.2	12.74	247.4	4.81	0.72	76.50	5.33
870813	105638	791.8	127.	19.91	11.88	63.8	12.85	247.4	4.81	1.64	76.46	5.33
870813	105643	791.1	134.	19.76	11.97	64.9	12.96	256.0	12.72	1.43	76.50	5.33
870813	105648	790.3	134.	19.86	11.90	64.0	12.85	256.0	12.72	8888.88	76.50	5.33
870813	105653	789.3	134.	19.58	12.06	65.9	13.03	256.0	12.72	8888.88	76.50	5.33
870813	105657	788.3	134.	19.56	12.10	66.1	13.07	8888.9	8888.88	8888.88	76.50	5.33
870813	105702	787.2	134.	19.44	12.15	66.8	13.10	8888.9	8888.88	8888.88	76.46	5.33
870813	105707	786.1	134.	19.23	12.22	67.9	13.17	8888.9	8888.88	8888.88	76.46	5.33
870813	105712	785.1	134.	19.08	12.24	68.6	13.18	8888.9	8888.88	8888.88	76.57	5.40
870813	105717	784.1	134.	18.93	12.22	69.1	13.14	8888.9	8888.88	8888.88	77.22	5.72
870813	105722	782.6	134.	18.89	12.21	69.0	13.09	8888.9	8888.88	8888.88	77.80	6.16
870813	105726	780.8	134.	18.69	12.23	69.9	13.08	8888.9	8888.88	8888.88	78.05	6.77
870813	105731	779.2	134.	18.72	12.23	69.6	13.05	8888.9	8888.88	8888.88	78.08	6.98
870813	105736	778.2	134.	18.34	12.26	71.4	13.07	8888.9	8888.88	8888.88	78.08	7.02
870813	105741	777.5	134.	18.04	12.19	72.3	12.97	8888.9	8888.88	8888.88	78.08	7.02
870813	105746	777.1	134.	17.77	12.22	73.7	13.00	8888.9	8888.88	8888.88	78.05	6.98
870813	105750	777.4	134.	17.97	12.13	72.2	12.89	8888.9	8888.88	8888.88	78.05	6.98
870813	105755	88888888	88888888	17.91	88888888	88888888	88888888	88888888	88888888	88888888	78.08	7.02
870813	105800	88888888	88888888	17.88	88888888	88888888	88888888	88888888	88888888	88888888	78.08	6.98
870813	105820	773.5	326.	17.50	12.20	74.4	12.90	8888.9	8888.88	1.99	78.23	7.02
870813	105825	773.2	330.	17.46	12.19	74.5	12.88	260.2	12.15	0.73	78.19	7.02
870813	105829	773.0	333.	17.17	12.26	76.4	12.97	260.2	12.15	0.57	78.19	7.02
870813	105834	772.8	334.	17.15	12.15	75.7	12.82	260.2	12.15	0.36	78.19	7.02
870813	105839	772.7	336.	16.96	12.13	76.5	12.80	258.2	4.56	0.37	78.19	6.98

DATE	TMDAY	PR=MB	PHT=M	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AR=MS	AZ=DG	EL=DG
870813	105844	772.4	340.	16.84	12.12	77.0	12.78	258.2	4.56	0.73	78.19	6.98
870813	105849	771.9	345.	16.76	12.11	77.2	12.75	258.2	4.56	1.09	78.23	6.98
870813	105853	771.6	349.	16.80	12.04	76.6	12.67	258.2	5.96	0.74	78.19	7.02
870813	105858	771.2	352.	16.86	12.04	76.3	12.65	258.2	5.96	0.74	78.19	6.98
870813	105903	771.1	354.	17.01	11.99	75.2	12.59	258.2	5.96	0.37	78.19	6.98
870813	105908	770.7	358.	16.81	12.04	76.5	12.65	260.3	6.72	0.92	78.26	7.02
870813	105913	770.4	362.	16.72	12.05	76.9	12.65	260.3	6.72	0.74	78.26	7.02
870813	105918	770.0	366.	16.70	12.08	77.2	12.68	260.3	6.72	0.91	78.23	7.06
870813	105922	769.6	371.	16.51	12.11	78.3	12.71	256.6	4.33	0.92	78.23	7.09
870813	105927	769.1	376.	16.35	12.10	78.9	12.69	256.6	4.33	1.10	78.19	7.13
870813	105932	768.8	380.	16.29	12.00	78.6	12.56	256.6	4.33	0.74	78.16	7.20
870813	105937	768.2	386.	16.31	11.96	78.1	12.49	258.2	2.78	1.28	78.23	7.24
870813	105942	767.7	391.	16.33	11.96	78.0	12.49	258.2	2.78	1.11	78.37	7.31
870813	105946	767.2	397.	16.38	11.98	77.9	12.51	258.2	2.78	1.29	78.44	7.38
870813	105951	766.7	403.	16.47	11.97	77.3	12.48	271.5	4.66	1.11	78.52	7.42
870813	105956	766.2	408.	16.33	12.02	78.2	12.53	271.5	4.66	1.11	78.62	7.45
870813	110001	766.0	410.	16.41	12.00	77.7	12.51	271.5	4.66	0.38	78.73	7.42
870813	110006	766.0	411.	16.28	12.05	78.7	12.57	269.6	4.99	0.18	78.77	7.34
870813	110011	766.1	409.	16.20	12.07	79.2	12.59	269.6	4.99	-0.36	78.80	7.24
870813	110015	766.3	407.	16.13	12.07	79.6	12.60	269.6	4.99	-0.38	78.80	7.13
870813	110020	766.5	404.	15.98	12.08	80.4	12.61	259.6	9.31	-0.55	78.80	6.95
870813	110025	766.9	400.	15.92	12.01	80.3	12.54	259.6	9.31	-0.91	78.84	6.80
870813	110030	766.8	401.	15.95	11.98	80.0	12.49	259.6	9.31	0.17	78.84	6.73
870813	110035	766.8	401.	15.96	11.95	79.7	12.45	259.7	9.97	0.00	78.84	6.66
870813	110040	767.1	398.	15.95	11.93	79.7	12.44	259.7	9.97	-0.55	78.88	6.52
870813	110044	767.4	395.	16.00	11.89	79.2	12.40	259.7	9.97	-0.74	78.88	6.34
870813	110049	767.7	391.	15.92	11.89	79.7	12.41	258.0	10.01	-0.74	78.80	6.19
870813	110054	768.0	388.	15.85	11.89	80.0	12.41	258.0	10.01	-0.74	78.73	6.05
870813	110059	768.4	383.	15.86	11.84	79.7	12.36	258.0	10.01	-0.92	78.73	5.90
870813	110104	768.8	380.	15.84	11.83	79.8	12.35	256.3	7.30	-0.73	78.73	5.83
870813	110109	769.1	376.	15.82	11.81	79.8	12.33	256.3	7.30	-0.74	78.77	5.83
870813	110113	769.5	371.	15.82	11.80	79.7	12.32	256.3	7.30	-0.92	78.77	5.87
870813	110118	769.7	369.	15.84	11.77	79.5	12.29	78.7	5.82	-0.56	78.73	5.87
870813	110123	770.3	363.	15.86	11.74	79.2	12.27	78.7	5.82	-1.27	78.77	5.87
870813	110128	770.8	357.	15.89	11.71	78.9	12.24	78.7	5.82	-1.09	78.77	5.87
870813	110133	771.2	353.	15.94	11.70	78.6	12.22	78.7	10.55	-0.93	78.73	5.83
870813	110137	771.9	345.	15.96	11.71	78.7	12.26	78.7	10.55	-1.66	78.77	5.87
870813	110142	772.4	340.	15.98	11.67	78.3	12.21	78.7	10.55	-1.09	78.80	5.76
870813	110147	773.0	333.	16.07	11.64	77.8	12.18	77.7	7.76	-1.46	78.77	5.72
870813	110152	773.4	328.	16.25	11.56	76.4	12.09	77.7	7.76	-0.91	78.77	5.72
870813	110157	773.5	327.	16.38	11.53	75.6	12.06	77.7	7.76	-0.19	78.77	5.72
870813	110202	773.7	325.	16.43	11.57	75.6	12.11	77.8	8.39	-0.36	78.80	5.72
870813	110206	773.7	325.	16.39	11.61	76.1	12.16	77.8	8.39	-0.01	78.77	5.69
870813	110211	774.1	321.	16.64	11.55	74.5	12.09	77.8	8.39	-0.90	78.77	5.72
870813	110216	774.3	318.	16.82	11.55	73.7	12.10	80.7	4.20	-0.55	78.77	5.72
870813	110221	774.5	316.	16.88	11.57	73.6	12.13	80.7	4.20	-0.56	78.80	5.72
870813	110226	774.9	312.	16.64	11.62	75.1	12.20	80.7	4.20	-0.71	78.80	5.65
870813	110231	774.9	311.	16.61	11.66	75.4	12.25	281.8	1.06	-0.20	78.88	5.58
870813	110235	775.0	311.	16.69	11.62	74.8	12.20	281.8	1.06	8888.88	78.95	5.58
870813	110240	775.1	311.	16.82	11.58	74.0	12.15	281.8	1.06	8888.88	79.02	5.51
870813	110245	774.9	311.	16.81	11.59	74.1	12.16	8888.9	8888.88	8888.88	79.06	5.47
870813	110250	775.2	308.	16.79	11.60	74.3	12.19	8888.9	8888.88	-0.18	79.06	5.47
870813	110255	775.2	308.	16.76	11.68	74.9	12.28	8888.9	8888.88	8888.88	79.06	5.47
870813	110259	775.5	308.	16.75	11.70	75.1	12.32	8888.9	8888.88	8888.88	79.02	5.47
870813	110304	775.8	308.	16.74	11.70	75.2	12.32	8888.9	8888.88	8888.88	79.06	5.47
870813	110309	776.3	308.	16.75	11.70	75.2	12.32	8888.9	8888.88	8888.88	79.06	5.47

DATE	TMDAY	PR=MB	PHT=M	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AR=MS	AZ=DG	EL=DG
870813	110314	776.3	296.	16.92	11.62	73.9	12.23	70.2	1.48	-0.48	79.06	5.47
870813	110319	776.8	296.	16.95	11.64	73.9	12.27	70.2	1.48	8888.88	79.02	5.47
870813	110324	777.1	288.	17.08	11.60	73.1	12.22	70.2	1.48	-0.90	79.02	5.36
870813	110328	777.5	288.	17.10	11.62	73.2	12.26	8888.9	8888.88	8888.88	79.09	5.26
870813	110333	777.7	288.	17.15	11.60	72.8	12.23	8888.9	8888.88	8888.88	79.09	5.15
870813	110338	778.1	288.	17.05	11.66	73.7	12.32	8888.9	8888.88	8888.88	79.09	5.04
870813	110343	778.5	272.	17.38	11.55	71.5	12.18	261.0	2.00	-0.82	79.09	4.93
870813	110348	778.9	267.	17.40	11.56	71.2	12.20	261.0	2.00	-0.90	79.09	4.82
870813	110353	779.2	264.	17.50	11.59	71.3	12.25	261.0	2.00	-0.71	79.09	4.75
870813	110358	779.5	261.	17.37	11.72	72.7	12.41	270.0	0.00	-0.55	79.09	4.72
870813	110402	779.8	258.	17.28	11.70	73.0	12.40	270.0	0.00	-0.72	79.09	4.64
870813	110407	779.9	257.	17.29	11.71	73.0	12.41	270.0	0.00	-0.19	79.16	4.57
870813	110412	780.1	254.	17.37	11.68	72.5	12.38	263.9	5.05	-0.54	79.20	4.50
870813	110417	780.4	251.	17.68	11.58	70.6	12.26	263.9	5.05	-0.72	79.20	4.46
870813	110422	780.8	246.	17.92	11.55	69.3	12.23	263.9	5.05	-0.90	79.16	4.46
870813	110427	781.1	244.	17.72	11.69	71.1	12.41	80.1	8.85	-0.55	79.16	4.46
870813	110431	781.4	240.	17.85	11.67	70.4	12.40	80.1	8.85	-0.74	79.20	4.46
870813	110436	781.7	237.	18.10	11.58	68.8	12.28	80.1	8.85	-0.73	79.20	4.46
870813	110441	782.3	237.	18.29	11.59	68.1	12.30	8888.9	8888.88	8888.88	79.16	4.46
870813	110446	782.7	225.	18.50	11.57	67.2	12.29	8888.9	8888.88	-1.17	79.16	4.46
870813	110451	783.2	220.	18.50	11.62	67.5	12.37	8888.9	8888.88	-1.07	79.16	4.46
870813	110456	783.6	216.	18.58	11.63	67.2	12.38	78.9	13.41	-0.91	79.20	4.46
870813	110500	784.2	216.	18.55	11.72	67.9	12.51	78.9	13.41	8888.88	79.24	4.32
870813	110505	784.7	216.	18.95	11.53	65.3	12.28	78.9	13.41	8888.88	79.24	4.28
870813	110510	785.3	216.	19.15	11.44	64.0	12.17	8888.9	8888.88	8888.88	79.24	4.14
870813	110515	785.8	192.	19.13	11.48	64.3	12.23	8888.9	8888.88	-1.21	79.24	4.03
870813	110520	786.2	187.	19.25	11.49	63.9	12.25	8888.9	8888.88	-1.09	79.24	3.92
870813	110524	786.6	183.	19.34	11.60	64.2	12.40	259.2	0.43	-0.92	79.20	3.82
870813	110529	787.1	178.	19.25	11.68	65.1	12.52	259.2	0.43	-1.07	79.13	3.74
870813	110534	787.4	174.	19.23	11.72	65.4	12.58	259.2	0.43	-0.72	79.09	3.67
870813	110539	787.8	170.	19.38	11.70	64.7	12.55	86.3	3.72	-0.90	79.06	3.64
870813	110544	788.2	165.	19.34	11.78	65.3	12.67	86.3	3.72	-0.89	79.02	3.60
870813	110549	788.5	162.	19.35	11.82	65.5	12.72	86.3	3.72	-0.73	78.95	3.49
870813	110553	788.8	159.	19.28	11.89	66.2	12.82	89.4	2.55	-0.71	78.91	3.42
870813	110558	789.2	155.	19.39	11.84	65.5	12.76	89.4	2.55	-0.72	78.88	3.38
870813	110603	789.6	151.	19.39	11.87	65.7	12.80	89.4	2.55	-0.90	78.80	3.31
870813	110608	789.8	148.	19.56	11.85	64.9	12.78	82.8	4.96	-0.54	78.80	3.24
870813	110613	790.1	145.	19.70	11.85	64.4	12.79	82.8	4.96	-0.72	78.73	3.20
870813	110618	790.4	141.	19.70	11.92	64.8	12.89	82.8	4.96	-0.71	78.73	3.13
870813	110622	790.8	137.	19.78	11.89	64.3	12.85	79.5	8.95	-0.87	78.77	3.13
870813	110627	791.1	134.	19.94	11.87	63.6	12.84	79.5	8.95	-0.72	78.73	3.13
870813	110632	791.5	130.	19.92	11.90	63.9	12.88	79.5	8.95	-0.71	78.77	3.13
870813	110637	791.5	130.	19.78	12.03	65.1	13.04	79.5	7.59	-0.01	78.73	3.13
870813	110642	791.8	127.	19.67	12.07	65.8	13.09	79.5	7.59	-0.71	78.77	3.13
870813	110647	792.2	122.	19.61	12.04	65.9	13.07	79.5	7.59	-0.88	78.73	3.13
870813	110651	792.6	118.	19.42	12.03	66.7	13.07	78.7	14.59	-0.87	78.73	3.13
870813	110656	792.7	116.	19.42	11.99	66.5	13.01	78.7	14.59	-0.37	78.77	3.13
870813	110701	793.3	110.	19.48	11.97	66.2	13.00	78.7	14.59	-1.26	78.73	3.10
870813	110706	793.6	110.	19.64	11.91	65.2	12.93	8888.9	8888.88	8888.88	78.55	3.02
870813	110711	794.0	103.	19.89	11.87	64.1	12.89	8888.9	8888.88	-0.80	78.41	2.99
870813	110716	794.1	102.	19.71	11.93	65.1	12.97	8888.9	8888.88	-0.18	78.26	2.95
870813	110720	793.9	103.	19.58	11.91	65.5	12.94	89.9	3.82	0.35	78.12	2.95
870813	110725	793.7	106.	19.42	11.83	65.7	12.83	89.9	3.82	0.52	78.05	2.99
870813	110730	793.3	109.	19.27	11.85	66.4	12.86	89.9	3.82	0.72	78.05	3.02
870813	110735	792.9	114.	19.35	11.79	65.7	12.76	257.1	10.68	1.06	78.05	3.06
870813	110740	792.5	119.	19.46	11.73	64.9	12.68	257.1	10.68	0.90	78.08	3.17

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870813	110745	792.0	124.	19.44	11.71	64.8	12.65	257.1	10.68	1.05	78.08	3.20
870813	110749	791.6	128.	19.26	11.76	65.8	12.71	260.9	5.80	0.90	78.16	3.24
870813	110754	791.1	133.	19.04	11.79	66.8	12.73	260.9	5.80	1.07	78.16	3.31
870813	110759	790.8	137.	18.89	11.77	67.3	12.70	260.9	5.80	0.71	78.19	3.35
870813	110804	790.7	139.	19.01	11.67	66.2	12.57	258.9	7.83	0.37	78.19	3.38
870813	110809	790.3	142.	19.17	11.64	65.4	12.53	258.9	7.83	0.70	78.16	3.38
870813	110813	790.5	140.	19.26	11.60	64.8	12.48	258.9	7.83	-0.35	78.08	3.38
870813	110818	790.7	139.	19.21	11.60	65.0	12.48	243.8	1.66	-0.36	78.05	3.35
870813	110823	791.0	135.	19.17	11.63	65.4	12.52	243.8	1.66	-0.71	77.98	3.31
870813	110828	791.4	131.	19.48	11.51	63.5	12.38	243.8	1.66	-0.87	77.94	3.28
870813	110833	791.8	127.	19.24	11.75	65.9	12.70	82.9	5.82	-0.91	77.87	3.17
870813	110838	792.2	121.	19.62	11.60	63.5	12.51	82.9	5.82	-1.07	77.87	3.13
870813	110842	792.8	115.	19.61	11.54	63.3	12.45	82.9	5.82	-1.23	77.80	2.99
870813	110847	793.5	115.	19.80	11.53	62.6	12.45	8888.9	8888.88	8888.88	77.80	2.95
870813	110852	793.9	103.	19.74	11.60	63.2	12.54	8888.9	8888.88	-1.24	77.72	2.84
870813	110857	794.4	103.	19.51	11.70	64.7	12.67	8888.9	8888.88	8888.88	77.69	2.77
870813	110902	794.8	103.	19.48	11.72	65.0	12.71	8888.9	8888.88	8888.88	77.65	2.74
870813	110907	795.2	103.	19.73	11.68	63.8	12.67	8888.9	8888.88	8888.88	77.65	2.70
870813	110912	795.2	103.	19.50	11.81	65.4	12.84	8888.9	8888.88	8888.88	77.65	2.66
870813	110916	795.6	103.	19.55	11.75	64.9	12.76	8888.9	8888.88	8888.88	77.65	2.63
870813	110921	795.4	103.	19.33	11.79	66.0	12.81	8888.9	8888.88	8888.88	77.62	2.63
870813	110926	795.6	103.	19.13	11.79	66.8	12.81	8888.9	8888.88	8888.88	77.62	2.63
870813	110931	795.3	103.	19.07	11.74	66.8	12.75	8888.9	8888.88	8888.88	77.62	2.63
870813	110936	795.1	103.	19.02	11.71	66.8	12.71	8888.9	8888.88	8888.88	77.62	2.66
870813	110941	794.8	93.	19.07	11.66	66.3	12.64	8888.9	8888.88	-0.21	77.62	2.70
870813	110945	794.5	93.	19.13	11.68	66.1	12.66	8888.9	8888.88	8888.88	77.62	2.74
870813	110950	794.1	93.	19.35	11.63	64.9	12.59	8888.9	8888.88	8888.88	77.54	2.77
870813	110955	793.7	93.	19.42	11.63	64.6	12.58	8888.9	8888.88	8888.88	77.51	2.84
870813	111000	793.3	93.	19.41	11.65	64.7	12.59	8888.9	8888.88	8888.88	77.44	2.84
870813	111005	793.3	93.	19.28	11.69	65.4	12.64	8888.9	8888.88	8888.88	77.40	2.88
870813	111009	792.9	93.	19.49	11.63	64.3	12.56	8888.9	8888.88	8888.88	77.36	2.92
870813	111014	792.6	93.	19.30	11.73	65.5	12.68	8888.9	8888.88	8888.88	77.33	2.92
870813	111019	792.4	93.	18.94	11.78	67.3	12.74	8888.9	8888.88	8888.88	77.26	2.99
870813	111024	792.2	93.	18.83	11.73	67.4	12.67	8888.9	8888.88	8888.88	77.22	2.99
870813	111029	792.0	93.	18.89	11.65	66.7	12.56	8888.9	8888.88	8888.88	77.15	3.02
870813	111034	791.7	93.	18.70	11.64	67.5	12.55	8888.9	8888.88	8888.88	77.11	3.02
870813	111038	791.7	93.	18.63	11.63	67.7	12.54	8888.9	8888.88	8888.88	77.04	3.06
870813	111043	791.4	130.	18.66	11.57	67.2	12.45	235.7	0.73	0.59	77.00	3.06
870813	111048	791.4	130.	18.83	11.55	66.4	12.43	235.7	0.73	0.01	76.97	3.06
870813	111053	791.4	131.	18.74	11.56	66.8	12.44	235.7	0.73	0.17	76.93	3.10
870813	111058	791.3	132.	18.67	11.55	67.1	12.43	252.2	5.15	0.18	76.86	3.10
870813	111103	791.1	133.	18.76	11.49	66.4	12.35	252.2	5.15	0.35	76.79	3.10
870813	111107	791.1	133.	18.98	11.45	65.2	12.30	252.2	5.15	0.01	76.75	3.10
870813	111112	791.1	133.	18.98	11.47	65.3	12.32	166.8	0.32	0.00	76.75	3.10
870813	111117	791.0	134.	19.13	11.47	64.7	12.32	166.8	0.32	0.17	76.79	3.10
870813	111122	791.0	134.	19.41	11.43	63.3	12.26	166.8	0.32	8888.88	76.75	3.10
870813	111127	790.9	136.	19.80	11.41	61.7	12.23	270.0	0.00	0.18	76.75	3.10
870813	111131	790.7	136.	19.84	11.52	62.1	12.38	270.0	0.00	8888.88	76.79	3.10
870813	111136	790.6	139.	19.73	11.67	63.3	12.57	270.0	0.00	0.36	76.79	3.13
870813	111141	790.3	139.	19.71	11.76	63.9	12.68	8888.9	8888.88	8888.88	76.79	3.13
870813	111146	789.9	146.	19.81	11.86	64.0	12.80	8888.9	8888.88	0.71	76.79	3.10
870813	111151	789.7	149.	19.78	11.93	64.5	12.88	8888.9	8888.88	0.54	76.79	3.10
870813	111156	789.3	153.	19.61	12.07	65.8	13.05	256.8	10.72	0.89	76.75	3.13
870813	111200	789.1	156.	19.51	12.09	66.4	13.07	256.8	10.72	0.53	76.75	3.13
870813	111205	788.8	156.	19.60	12.07	65.9	13.04	256.8	10.72	8888.88	76.75	3.13
870813	111210	788.6	156.	19.85	12.04	64.7	13.00	8888.9	8888.88	8888.88	76.75	3.13

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  DATE    TMDAY    PR=MB    PHT=M    DT=DC    MR=GM    RH=PC    DW=DC    BD=DG    BS=MS    AR=MS    AZ=DG    EL=DG
870813   111215    788.3     156.    20.07    12.05     63.8    13.01   8888.9  8888.88  8888.88    76.79     3.10
870813   111220    788.0     156.    20.14    12.07     63.7    13.03   8888.9  8888.88  8888.88    76.75     3.13
870813   111225    796.4     156.    20.19    11.95     63.5    13.04   8888.9  8888.88  8888.88    76.75     3.10
870813   111230    700.0     156.    19.78    13.95     66.6    13.38   8888.9  8888.88  8888.88    76.79     3.10
870813   111234 88888888 88888888    19.88 88888888 88888888 88888888 88888888 88888888 88888888    76.79     3.13
870813   111239 88888888 88888888    19.58 88888888 88888888 88888888 88888888 88888888 88888888    76.75     3.28
870813   111244 88888888 88888888    18.54 88888888 88888888 88888888 88888888 88888888 88888888    76.64     3.38
870813   111249 88888888 88888888    17.45 88888888 88888888 88888888 88888888 88888888 88888888    76.54     3.42
870813   111254 88888888 88888888    16.82 88888888 88888888 88888888 88888888 88888888 88888888    76.43     3.46
870813   111259 88888888 88888888    15.99 88888888 88888888 88888888 88888888 88888888 88888888    76.32     3.56
870813   111303   -314.6     156.    15.29   -83.25    279.9    27.95   8888.9  8888.88  8888.88    76.28     3.64
870813   111308   -314.5     156.    15.32   -83.26    279.3    27.95   8888.9  8888.88  8888.88    76.21     3.71
870813   111313   -314.4     156.    15.31   -83.27    279.4    27.94   8888.9  8888.88  8888.88    76.18     3.82
870813   111318 88888888 88888888    15.27 88888888 88888888 88888888 88888888 88888888 88888888    76.07     3.92

870813   115635    769.0     376.    16.66    12.39     79.2    13.05   8888.9  8888.88     4.18  8888.88  8888.88
870813   115639    770.5     360.    16.61    12.41     79.8    13.10   8888.9  8888.88    -3.31    84.64     1.91
870813   115644    771.5     348.    16.54    12.44     80.4    13.15   8888.9  8888.88    -2.38    84.64     1.91
870813   115649    772.6     336.    16.48    12.46     81.0    13.20    267.7    98.15    -2.56    84.64     1.91
870813   115654    773.7     324.    16.57    12.43     80.4    13.18    267.7    98.15    -2.37    84.64     1.91
870813   115659    774.5     316.    16.96    12.32     77.8    13.06    267.7    98.15    -1.83    84.64     1.91
870813   115704    775.5     304.    17.03    12.33     77.7    13.10     84.6    59.48    -2.36    84.64     1.91
870813   115708    776.4     294.    17.24    12.29     76.4    13.06     84.6    59.48    -2.02    84.64     1.91
870813   115713    777.6     280.    17.13    12.37     77.6    13.19     84.6    59.48    -2.90    84.64     1.91
870813   115718    779.0     266.    17.45    12.25     75.5    13.07     84.6    72.92    -3.07    84.64     1.91
870813   115723    780.0     254.    17.38    12.29     76.2    13.14     84.6    72.92    -2.36    84.64     1.91
870813   115728    781.1     243.    17.53    12.24     75.2    13.09     84.6    72.92    -2.34    84.64     1.91
870813   115733    782.1     232.    17.76    12.20     74.0    13.07     84.6    72.88    -2.33    84.64     1.91
870813   115737    783.3     219.    17.87    12.24     73.9    13.15     84.6    72.88    -2.69    84.64     1.91
870813   115742    784.3     207.    17.94    12.27     73.8    13.19     84.6    72.88    -2.35    84.64     1.91
870813   115747 88888888 88888888    17.88 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115752 88888888 88888888    18.04 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115757    788.0     167.    18.14    12.36     73.7    13.38   8888.9  8888.88    -2.80    84.64     1.91
870813   115802    788.6     160.    18.17    12.41     74.0    13.45     84.6    73.51    -1.26    84.64     1.91
870813   115806    790.6     139.    18.70    12.34     71.3    13.40     84.6    73.51    -4.45    84.64     1.91
870813   115811    791.8     125.    19.04    12.27     69.6    13.35     84.6    73.51    -2.82    84.64     1.91
870813   115816 88888888 88888888    18.94 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115821 88888888 88888888    19.11 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115826 88888888 88888888    19.47 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115831 88888888 88888888    19.38 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115835    799.8      39.    19.32    12.14     68.3    13.33   8888.9  8888.88    -3.57    84.64     1.91
870813   115840    800.8      28.    19.64    12.04     66.5    13.23   8888.9  8888.88    -2.28    84.64     1.91
870813   115845    802.3      12.    19.73    12.11     66.7    13.35     84.6   107.89    -3.31    84.64     1.91
870813   115850 88888888 88888888    19.96 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115855 88888888 88888888    20.15 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115900    805.3     -20.    19.99    12.24     66.5    13.56    270.0     0.00    -2.21    84.64     1.91
870813   115904    806.4     -32.    20.07    12.27     66.4    13.62    270.0     0.00    -2.44    84.64     1.91
870813   115909    807.2     -40.    20.56    12.17     64.0    13.51    270.0     0.00    -1.73    84.64     1.91
870813   115914 88888888 88888888    20.69 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115919 88888888 88888888    20.54 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115924 88888888 88888888    20.54 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115928 88888888 88888888 68888888 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115933 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115938 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115943 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115948 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
870813   115953 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888 88888888    84.64     1.91
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NOTES ON FLIGHT 1 AIR SONDE DATA

The key to reading the data is given below:

column	parameter
1.	date
2.	time of day (local)
3.	pressure in mb
4.	height AGL in metres; note that this is the pressure altitude referenced to the launch site
5.	temperature in degrees C
6.	mixing ratio in g/kg
7.	relative humidity in %
8.	dew point in degrees C
9.	wind direction (true), but only when the balloon is being tracked by the theodolite
10.	wind speed in m/s
11.	rise rate in m/s
12.	theodolite azimuth
13.	theodolite elevation

- Launch was at 10:49:17

- There was a loss of data between 11:13 and 11:56 when a parked aircraft was between the Tracer and the ground station antenna,

ARGOS DATA FROM FLIGHT 2

```
01-13-1988     13:31:38        F64CBA
REMAINING CUT-DOWN TIME (MIN)                        112.4844
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      27.48333
PRESSURE(MB)                   804.5
TEMPERATURE(C)                 3.599999
HUMIDITY(%)                    57
POT. TEMP. (C)                 21.4
ANEM. COUNT(200/REV)           1822
INTERVALS PUMPING              0
INTERVALS VALVING              35
INTERNAL PRESS. (MB)           759.2
INTERNAL TEMP #1 (C)           20.5
INTERNAL TEMP #2 (C)           20.5

01-13-1988     13:32:29        F64CBA
REMAINING CUT-DOWN TIME (MIN)                        111.6348
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      28.33334
PRESSURE(MB)                   803.4
TEMPERATURE(C)                 3.599999
HUMIDITY(%)                    57
POT. TEMP. (C)                 21.5
ANEM. COUNT(200/REV)           836
INTERVALS PUMPING              0
INTERVALS VALVING              48
INTERNAL PRESS. (MB)           757.6
INTERNAL TEMP #1 (C)           20.6
INTERNAL TEMP #2 (C)           20.6

01-13-1988     13:33:20        F64CBA
REMAINING CUT-DOWN TIME (MIN)                        110.7832
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      29.2
PRESSURE(MB)                   802.5
TEMPERATURE(C)                 3.5
HUMIDITY(%)                    57
POT. TEMP. (C)                 21.4
ANEM. COUNT(200/REV)           147
INTERVALS PUMPING              0
INTERVALS VALVING              61
INTERNAL PRESS. (MB)           755.7
INTERNAL TEMP #1 (C)           19.5
INTERNAL TEMP #2 (C)           19.5

01-13-1988     13:34:11        F64CBA
REMAINING CUT-DOWN TIME (MIN)                        109.9336
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      30.05
PRESSURE(MB)                   801.3
TEMPERATURE(C)                 3.699997
HUMIDITY(%)                    57
POT. TEMP. (C)                 21.8
ANEM. COUNT(200/REV)           119
INTERVALS PUMPING              0
INTERVALS VALVING              74
INTERNAL PRESS. (MB)           754.7
INTERNAL TEMP #1 (C)           18.6
INTERNAL TEMP #2 (C)           18.6

01-13-1988    13:35:03      F64CBA
REMAINING CUT-DOWN TIME (MIN)                      109.0664
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      30.91667
PRESSURE(MB)                   799
TEMPERATURE(C)                 3.800003
HUMIDITY(%)                    57
POT. TEMP. (C)                 22.2
ANEM. COUNT(200/REV)           1090
INTERVALS PUMPING              0
INTERVALS VALVING              87
INTERNAL PRESS. (MB)           752.4
INTERNAL TEMP #1 (C)           19.5
INTERNAL TEMP #2 (C)           19.5

01-13-1988    13:35:55      F64CBA
REMAINING CUT-DOWN TIME (MIN)                      108.2012
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      31.78333
PRESSURE(MB)                   795.1
TEMPERATURE(C)                 3.900002
HUMIDITY(%)                    57
POT. TEMP. (C)                 22.7
ANEM. COUNT(200/REV)           1216
INTERVALS PUMPING              0
INTERVALS VALVING              100
INTERNAL PRESS. (MB)           750.1
INTERNAL TEMP #1 (C)           19.6
INTERNAL TEMP #2 (C)           19.6

01-13-1988    13:36:47      F64CBA
REMAINING CUT-DOWN TIME (MIN)                      107.334
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      32.65
PRESSURE(MB)                   793.4
TEMPERATURE(C)                 3.400002
HUMIDITY(%)                    57
POT. TEMP. (C)                 22.3
ANEM. COUNT(200/REV)           1483
INTERVALS PUMPING              0
INTERVALS VALVING              113
INTERNAL PRESS. (MB)           748.9
INTERNAL TEMP #1 (C)           19.5
INTERNAL TEMP #2 (C)           19.5

01-13-1988    13:37:38      F64CBA
REMAINING CUT-DOWN TIME (MIN)                      106.4844
OPEN VALVE
CONTROL PROG. KEY              4
TARGET CONTROL VALUE           0
TIME(MIN)                      33.5
PRESSURE(MB)                   793.3
TEMPERATURE(C)                 2.900002
HUMIDITY(%)                    58
POT. TEMP. (C)                 21.8
```

NOTES ON FLIGHT 2 ARGOS DATA

- Launch time was 13:29 (1:29 pm local time).
- Note that the USART/machine language modifications for reading the sensors installed since flight 1 have eliminated the sensor read errors.
- The internal pressure sensor calibration was in error. That's why the internal pressure reads lower than the ambient pressure, even though it was in fact higher.
- There was a discrepancy in the time base used by the Argos data system and that used by the ADAS system which received the AIR sonde data. The discrepancy was between one and two minutes.
- Argos data was lost in mid transmission at about 13:38 (as indicated by the Argos data system clock) when the payload was lost to the wind shear.

AIR SONDE DATA FROM FLIGHT 2

DATE	TMDAY	PR=MB	PHT=F	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AZ=DG	EL=DG	AR=MS
880113	132816	807.4	6569.	5.40	2.81	40.6	-6.92	270.0	0.00	0.00	0.00	0.00
880113	132829	807.4	6571.	4.36	2.66	41.2	-7.64	270.0	0.00	0.00	0.00	0.00
880113	132843	807.3	6574.	4.40	2.79	43.1	-7.04	270.0	0.00	0.00	0.00	0.16
880113	132857	807.3	6571.	4.30	2.63	40.9	-7.79	270.0	0.00	34.99	0.00	0.01
880113	132911	806.1	6612.	4.29	2.61	40.6	-7.89	270.0	0.00	34.96	9.29	0.93
880113	132925	806.3	6607.	5.37	2.80	40.3	-7.01	270.0	0.00	-2.88	10.98	-0.47
880113	132939	806.1	6612.	5.15	2.68	39.2	-7.58	270.0	0.00	-9.94	10.76	0.15
880113	132953	806.5	6600.	5.90	2.78	38.6	-7.11	180.0	4.31	-14.87	10.76	-0.31
880113	133007	806.9	6586.	5.85	2.71	37.8	-7.42	180.0	4.31	-17.03	10.69	-0.31
880113	133021	807.1	6579.	5.81	2.63	36.8	-7.80	270.0	0.00	-17.03	10.69	-0.30
880113	133035	807.0	6581.	5.85	2.63	36.7	-7.82	270.0	0.00	-17.28	3.67	0.16
880113	133049	807.1	6579.	5.95	2.63	36.4	-7.81	270.0	0.00	-21.24	2.59	0.16
880113	133103	807.0	6581.	6.19	2.64	36.1	-7.73	270.0	0.00	-22.28	2.30	0.31
880113	133117	807.1	6579.	5.96	2.58	35.8	-8.01	270.0	0.00	-23.00	2.30	0.16
880113	133130	806.8	6589.	6.35	2.62	35.3	-7.85	270.0	0.00	-23.62	2.45	0.16
880113	133144	806.8	6589.	6.44	2.60	34.8	-7.96	270.0	0.00	-24.52	2.48	-0.15
880113	133158	806.9	6586.	6.49	2.60	34.7	-7.96	270.0	0.00	-25.20	2.09	-0.31
880113	133212	807.0	6584.	6.51	2.60	34.7	-7.92	270.0	0.00	-25.63	1.58	-0.00
880113	133226	807.0	6582.	6.94	2.67	34.6	-7.58	270.0	0.00	-25.70	1.55	0.16
880113	133240	807.2	6577.	6.75	2.63	34.5	-7.78	270.0	0.00	-25.70	1.55	0.00
880113	133254	806.8	6589.	5.57	2.45	34.9	-8.69	270.0	0.00	-25.70	1.55	0.78
880113	133308	806.5	6599.	5.10	2.33	34.2	-9.36	270.0	0.00	-30.06	1.58	0.47
880113	133322	805.9	6618.	5.25	2.34	34.1	-9.28	270.0	0.00	-30.64	1.58	0.63
880113	133336	805.6	6628.	5.14	2.32	34.0	-9.40	270.0	0.00	-30.92	1.66	0.31
880113	133350	805.6	6630.	6.35	2.56	34.5	-8.16	270.0	0.00	-31.46	1.62	0.16
880113	133403	805.1	6645.	7.40	2.79	34.9	-7.09	143.2	28.05	-32.15	1.91	0.16
880113	133417	804.8	6655.	7.75	2.87	35.0	-6.71	143.2	28.05	-32.44	2.09	0.01
880113	133431	804.6	6662.	7.72	2.91	35.6	-6.53	142.0	3.20	-32.76	2.16	-0.15
880113	133445	804.3	6672.	6.97	2.71	34.9	-7.47	142.0	3.20	-33.19	2.23	0.31
880113	133459	804.0	6684.	6.51	2.60	34.6	-7.99	142.0	4.86	-33.62	2.34	0.16
880113	133513	803.5	6701.	6.36	2.50	33.6	-8.48	130.1	1.45	-33.91	2.56	0.47
880113	133527	803.0	6715.	6.15	2.47	33.6	-8.67	130.1	1.45	-34.13	2.84	0.47
880113	133541	802.4	6737.	6.11	2.46	33.5	-8.73	330.4	2.25	-34.20	3.13	0.63
880113	133555	801.4	6769.	5.80	2.39	33.3	-9.09	330.4	2.25	-34.13	3.56	0.64
880113	133609	800.1	6812.	5.69	2.37	33.3	-9.21	146.8	5.00	-33.98	4.25	0.60
880113	133623	799.1	6846.	5.67	2.33	32.7	-9.43	181.4	0.72	-33.52	4.72	0.79
880113	133636	798.3	6875.	5.69	2.33	32.5	-9.48	181.4	0.72	-33.48	5.04	0.79
880113	133650	797.3	6907.	6.24	2.41	32.4	-9.06	151.4	3.14	-33.08	5.54	0.64
880113	133704	796.3	6941.	5.56	2.31	32.5	-9.60	151.4	3.14	-32.58	5.94	0.80
880113	133718	795.7	6960.	5.25	2.30	33.1	-9.66	276.3	0.80	-32.22	6.16	0.16
880113	133732	795.8	6958.	4.49	2.20	33.3	-10.23	161.0	1.72	-31.97	6.12	0.01
880113	133746	796.0	6951.	4.92	2.31	34.0	-9.60	161.0	1.72	-31.64	5.90	0.01
880113	133800	796.0	6951.	5.73	2.46	34.2	-8.83	167.7	0.64	-31.72	5.76	0.01
880113	133814	795.6	6963.	4.81	2.30	34.1	-9.65	167.7	0.64	-31.72	5.76	0.16
880113	133828	795.8	6959.	6.07	2.48	33.6	-8.73	147.6	2.62	-31.93	5.65	-0.32
880113	133842	796.6	6930.	6.78	2.62	33.9	-7.99	136.8	0.84	-31.93	5.11	-0.65
880113	133855	797.6	6896.	7.42	2.74	33.9	-7.42	136.8	0.84	-32.11	4.68	-0.64
880113	133909	797.4	6903.	7.43	2.71	33.5	-7.57	144.1	4.70	-32.29	4.43	0.64
880113	133923	797.0	69[illegible]6.	8.77	2.97	33.5	-6.38	144.1	4.70	-31.86	4.64	0.01
880113	133937	796.5	6933.	7.17	2.71	34.1	-7.57	234.2	0.72	-30.78	4.82	0.48
880113	133951	792.7	7062.	5.52	2.36	33.2	-9.38	238.6	2.06	-29.48	6.48	3.54
880113	134005	787.9	7226.	4.28	2.12	32.3	-10.81	238.6	2.06	-25.81	9.00	3.70
880113	134019	783.4	7378.	3.61	2.05	32.6	-11.29	272.8	7.56	-20.81	11.16	3.25
880113	134033	779.6	7504.	2.94	2.06	34.1	-11.33	272.8	7.56	-14.58	12.85	2.77
880113	134047	774.9	7666.	2.85	2.10	34.8	-11.15	254.5	9.15	-9.43	14.87	3.78

DATE	TMDAY	PR=MB	PHT=F	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AZ=DG	EL=DG	AR=MS
880113	134100	770.9	7805.	3.22	2.20	35.4	-10.61	249.0	8.43	-4.25	16.38	2.83
880113	134114	766.1	7969.	3.04	2.23	36.0	-10.55	249.0	8.43	1.08	17.71	4.00
880113	134128	761.3	8138.	2.87	2.24	36.4	-10.55	247.7	9.23	6.16	18.94	3.72
880113	134142	756.6	8301.	2.85	2.29	37.0	-10.39	247.7	9.23	11.12	19.73	3.40
880113	134156	752.0	8462.	2.28	2.39	40.0	-9.89	244.2	11.39	16.27	20.05	3.94
880113	134210	748.2	8598.	1.67	2.43	42.3	-9.76	254.4	12.74	21.89	20.27	2.76
880113	134224	744.5	8726.	1.79	2.53	43.5	-9.30	254.4	12.74	26.42	20.41	2.79
880113	134238	740.4	8873.	2.64	2.72	43.6	-8.48	258.4	12.62	30.71	20.56	2.99
880113	134252	736.6	9009.	2.14	2.63	43.5	-8.98	258.4	12.62	34.96	20.63	2.32
880113	134305	733.1	9138.	1.32	2.51	43.8	-9.62	266.9	12.24	38.92	20.56	3.01
880113	134319	729.8	9256.	0.79	2.42	43.7	-10.15	265.8	12.20	41.83	20.34	2.66
880113	134333	726.2	9384.	0.18	2.35	44.2	-10.54	265.8	12.20	44.60	20.27	2.86
880113	134347	722.9	9506.	0.33	2.41	44.7	-10.28	265.6	11.93	47.30	20.09	2.69
880113	134401	719.5	9630.	1.52	2.62	44.3	-9.30	265.6	11.93	49.64	19.80	2.74
880113	134415	715.7	9768.	0.52	2.43	44.0	-10.30	268.6	12.91	51.77	19.48	3.45
880113	134429	712.1	9901.	-0.38	2.34	45.0	-10.84	257.7	13.11	53.42	19.22	3.27
880113	134443	708.4	10038.	0.00	2.45	45.5	-10.35	257.7	13.11	54.90	19.08	2.78
880113	134457	704.7	10176.	-0.28	2.41	45.4	-10.62	263.8	11.67	56.66	18.79	2.80
880113	134511	701.0	10311.	-1.34	2.38	48.2	-10.86	263.8	11.67	57.74	18.61	3.15
880113	134524	697.4	10447.	-2.18	2.36	50.6	-11.01	260.0	14.01	58.86	18.32	2.62
880113	134538	694.0	10575.	-2.68	2.45	54.3	-10.61	260.4	13.64	59.94	18.00	2.99
880113	134552	690.2	10718.	-2.81	2.40	53.5	-10.92	260.4	13.64	60.88	17.78	3.38
880113	134606	686.4	10862.	-2.39	2.26	48.5	-11.74	258.8	14.64	61.81	17.53	3.22
880113	134620	682.5	11007.	-3.11	2.15	48.4	-12.45	258.8	14.64	62.75	17.35	2.88
880113	134634	678.7	11153.	-1.96	2.16	44.5	-12.42	262.1	14.86	63.76	17.17	3.28
880113	134648	675.0	11295.	-2.25	2.06	43.1	-13.07	265.6	14.33	64.62	16.99	2.91
880113	134702	671.3	11440.	-2.52	2.02	42.8	-13.39	265.6	14.33	65.66	16.81	3.14
880113	134716	667.4	11592.	-3.51	1.86	42.3	-14.45	270.8	16.46	66.89	16.56	3.15
880113	134730	663.7	11736.	-3.72	1.85	42.4	-14.61	270.8	16.46	67.57	16.38	2.97
880113	134744	659.9	11884.	-3.65	1.82	41.3	-14.85	264.6	17.07	68.36	16.20	3.57
880113	134758	656.4	12020.	-4.21	1.74	40.9	-15.49	266.8	17.46	69.12	15.95	3.19
880113	134811	652.8	12163.	-4.79	1.60	39.0	-16.57	266.8	17.46	69.91	15.77	2.63
880113	134825	649.1	12310.	-5.45	1.41	36.1	-18.08	269.7	16.12	70.49	15.62	3.41
880113	134839	645.6	12449.	-5.57	1.34	34.5	-18.71	269.7	16.12	71.03	15.52	2.84
880113	134853	641.9	12597.	-5.63	1.37	35.2	-18.55	266.3	16.03	71.50	15.41	3.26
880113	134907	638.2	12745.	-4.30	1.53	35.3	-17.34	262.2	15.72	71.82	15.26	3.50
880113	134921	634.6	12892.	-5.44	1.25	31.3	-19.74	262.2	15.72	72.11	15.12	3.87
880113	134935	631.1	13031.	-5.64	1.17	29.5	-20.60	257.1	17.06	72.11	15.01	3.50
880113	134949	627.8	13167.	-6.08	1.14	29.5	-20.96	257.1	17.06	72.14	14.80	3.13
880113	135003	624.5	13301.	-6.16	1.13	29.3	-21.14	253.5	17.48	72.72	14.69	2.93
880113	135017	621.5	13427.	-6.34	1.08	28.4	-21.66	265.3	16.32	72.79	14.51	2.74
880113	135031	618.6	13546.	-6.29	1.07	27.8	-21.85	265.3	16.32	73.08	14.36	2.53
880113	135045	615.8	13663.	-6.27	1.05	27.0	-22.14	262.1	16.94	73.44	14.29	2.35
880113	135059	613.1	13774.	-5.05	1.16	27.2	-21.00	262.1	16.94	72.94	14.15	2.35
880113	135113	610.8	13872.	-5.91	1.10	27.4	-21.66	247.8	14.99	73.19	13.97	2.16
880113	135127	608.3	13977.	-6.15	1.11	28.0	-21.64	261.5	16.82	73.37	13.79	2.82
880113	135140	606.0	14073.	-5.38	1.19	28.3	-20.85	261.5	16.82	73.62	13.64	2.19
880113	135154	603.8	14166.	-5.91	1.17	28.8	-21.10	262.3	16.62	73.73	13.54	1.95
880113	135208	602.3	14233.	-6.28	1.16	29.3	-21.22	262.3	16.62	73.84	13.32	1.93
880113	135222	599.9	14335.	-6.09	1.17	29.1	-21.14	257.4	16.93	73.94	13.14	1.34
880113	135236	597.8	14422.	-6.23	1.16	29.1	-21.28	255.9	16.17	73.94	13.00	2.39
880113	135250	596.0	14500.	-7.57	1.10	30.4	-21.93	255.9	16.17	74.02	12.85	1.57
880113	135304	594.2	14580.	-8.22	1.09	31.6	-22.08	253.9	18.48	73.94	12.67	1.95
880113	135318	592.3	14660.	-8.81	1.08	32.7	-22.23	253.9	18.48	73.87	12.49	1.75
880113	135332	590.5	14737.	-8.75	1.09	32.9	-22.09	251.1	18.00	73.76	12.38	1.54
880113	135346	588.4	14828.	-8.52	1.09	32.1	-22.17	249.6	17.03	73.69	12.24	2.23

DATE	TMDAY	PR=MB	PHT=F	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AZ=DG	EL=DG	AR=MS
880113	135400	586.7	14899.	-7.00	1.15	30.0	-21.60	249.6	17.03	73.58	12.13	1.52
880113	135414	584.5	14999.	-6.19	1.18	28.7	-21.40	251.6	17.52	73.58	11.99	1.40
880113	135428	582.6	15082.	-6.75	1.13	28.8	-21.84	251.6	17.52	73.55	11.88	1.61
880113	135442	580.3	15181.	-7.63	1.06	28.6	-22.68	251.3	16.75	73.44	11.77	1.82
880113	135456	578.9	1524[illegible].	-7.75	1.02	27.8	-23.11	246.8	20.72	73.30	11.59	0.51
880113	135510	576.7	15340.	-7.55	1.01	27.0	-23.27	246.8	20.72	73.26	11.59	1.38
880113	135524	574.7	15431.	-6.90	1.03	26.2	-23.03	277.1	11.36	73.73	11.56	2.06
880113	135538	572.8	15516.	-6.39	1.07	26.0	-22.69	277.1	11.36	73.69	11.48	2.53
880113	135552	570.8	15603.	-8.35	0.94	26.4	-24.20	251.1	15.54	73.69	11.38	1.16
880113	135606	569.3	15671.	-8.53	0.95	27.0	-24.13	252.3	15.48	73.66	11.30	0.96
880113	135620	567.1	15768.	-8.82	0.93	27.1	-24.32	252.3	15.48	73.66	11.20	2.72
880113	135634	565.5	15839.	-8.93	0.94	27.5	-24.28	255.0	16.80	73.69	11.16	1.84
880113	135648	563.6	15924.	-8.92	0.94	27.5	-24.26	255.0	16.80	73.66	11.05	1.60
880113	135702	561.9	16002.	-9.10	0.93	27.4	-24.44	252.2	15.26	73.66	10.98	2.05
880113	135716	560.3	16074.	-8.39	0.96	26.7	-24.11	285.5	19.06	74.56	10.91	1.40
880113	135730	558.5	16156.	-7.86	1.01	26.7	-23.67	285.5	19.06	79.99	10.84	1.62
880113	135744	556.8	16235.	-7.75	1.02	26.9	-23.49	332.7	63.56	79.96	10.76	1.63
880113	135758	555.3	16304.	-7.68	1.04	27.1	-23.33	332.7	63.56	79.85	10.66	1.40
880113	135812	553.6	16379.	-8.65	0.93	26.1	-24.59	254.4	17.40	79.78	10.58	1.84
880113	135826	552.0	16455.	-8.78	0.90	25.3	-25.04	254.2	17.63	79.70	10.51	2.11
880113	135840	550.8	16510.	-9.07	0.87	25.1	-25.40	254.2	17.63	79.63	10.40	1.21
880113	135853	549.2	16582.	-8.97	0.86	24.5	-25.55	252.1	16.91	79.52	10.33	2.10
880113	135907	548.1	16634.	-8.49	0.88	24.2	-25.30	252.1	16.91	79.49	10.26	2.66
880113	135921	547.3	16674.	-8.51	0.88	24.2	-25.32	256.9	19.87	79.42	10.12	0.71
880113	135935	546.2	16725.	-8.90	0.87	24.5	-25.51	256.6	18.83	79.38	10.01	0.76
880113	135949	545.2	16768.	-8.52	0.89	24.2	-25.33	256.6	18.83	79.31	9.90	1.42
880113	140003	544.7	16794.	-8.34	0.89	23.9	-25.29	256.6	19.61	79.27	9.83	-0.18
880113	140017	544.1	16823.	-8.49	0.89	24.1	-25.34	256.6	19.61	79.24	9.68	-0.49
880113	140031	543.2	16862.	-7.91	0.92	23.9	-24.94	255.5	14.70	79.16	9.61	0.26
880113	140045	542.8	16883.	-7.87	0.93	23.9	-24.87	256.0	17.79	79.16	9.50	-0.00
880113	140059	542.4	16901.	-8.03	0.92	24.0	-25.00	256.0	17.79	79.13	9.36	0.90
880113	140113	542.0	16920.	-9.23	0.84	24.0	-25.99	256.2	20.11	79.09	9.25	0.50
880113	140127	542.1	16916.	-8.81	0.87	24.0	-25.64	256.2	20.11	79.06	9.14	-0.47
880113	140141	541.5	16944.	-6.78	1.01	23.8	-24.02	257.4	17.76	79.02	9.07	1.17
880113	140155	541.6	16936.	-5.85	1.05	23.1	-23.55	256.4	11.60	79.02	9.00	0.17
880113	140209	541.3	16954.	-5.91	1.05	23.2	-23.53	256.4	11.60	79.02	8.82	0.98
880113	140223	541.2	16956.	-5.84	1.05	23.1	-23.51	257.7	24.47	78.98	8.71	0.71
880113	140237	541.2	16959.	-6.60	0.99	23.0	-24.23	257.7	24.47	78.48	8.60	0.22
880113	140251	541.4	16948.	-7.11	0.95	23.0	-24.66	237.4	21.31	78.48	8.50	-0.30
880113	140305	541.3	16951.	-7.01	0.94	22.7	-24.73	256.6	17.24	78.44	8.39	-0.50
880113	140319	541.1	16960.	-7.08	0.95	22.9	-24.69	256.6	17.24	78.44	8.32	0.88
880113	140333	541.5	16943.	-6.09	1.03	23.1	-23.76	258.4	15.97	78.44	8.24	-0.67
880113	140347	541.3	16952.	-4.94	1.14	23.3	-22.65	258.4	15.97	78.48	8.10	0.24
880113	140401	541.1	16962.	-3.86	1.24	23.5	-21.67	258.4	21.92	78.44	8.03	0.44
880113	140415	541.1	16962.	-3.95	1.25	23.8	-21.60	258.4	17.02	78.44	7.92	-0.00
880113	140429	540.8	16975.	-4.54	1.21	24.1	-21.92	258.4	17.02	78.44	7.85	1.38
880113	140443	541.0	16968.	-4.23	1.25	24.3	-21.58	8888.9	8888.88	78.44	7.78	-0.23
880113	140457	540.9	16972.	-5.12	1.17	24.4	-22.29	8888.9	8888.88	78.44	7.70	-0.03
880113	140511	540.9	16972.	-6.84	1.04	24.6	-23.68	258.4	16.65	78.44	7.60	-0.44
880113	140525	540.7	16979.	-7.41	1.01	24.9	-24.02	258.4	18.83	78.44	7.52	-0.69
880113	140539	540.2	17003.	-6.99	1.08	25.9	-23.25	258.4	18.83	78.44	7.49	0.46
880113	140553	540.1	17010.	-7.84	1.05	27.0	-23.53	258.4	16.54	78.44	7.42	0.48
880113	140607	539.6	17032.	-7.14	1.14	27.7	-22.61	258.4	16.54	78.44	7.34	0.71
880113	140621	539.6	17032.	-7.05	1.16	28.0	-22.42	258.4	16.80	78.44	7.27	0.24
880113	140635	539.4	17043.	-7.47	1.13	28.1	-22.73	258.4	17.31	78.44	7.20	-0.25
880113	140649	539.0	17061.	-7.71	1.12	28.3	-22.88	258.4	17.31	78.44	7.13	0.22

DATE	TMDAY	PR=MB	PHI=F	DT=DC	MR=GM	RH=PC	DM=DC	BD=DG	BS=MS	AZ=DG	EL=DG	AR=MS
880113	140703	538.8	17071.	-7.53	1.14	28.5	-22.66	258.4	12.68	78.44	7.09	0.61
880113	140717	538.7	17074.	-7.76	1.11	28.2	-22.96	258.4	12.68	78.41	7.02	-0.69
880113	140731	538.1	17103.	-7.65	1.11	27.8	-23.00	256.8	24.04	78.37	6.95	1.17
880113	140745	538.0	17107.	-6.98	1.16	27.7	-22.49	258.4	18.86	78.41	6.88	0.95
880113	140759	537.8	17117.	-6.59	1.18	27.3	-22.32	258.4	18.86	78.44	6.84	0.91
880113	140813	537.9	17113.	-6.37	1.20	27.3	-22.12	254.9	11.65	78.37	6.77	0.22
880113	140827	537.8	17120.	-5.77	1.27	27.6	-21.49	254.9	11.65	78.41	6.77	-1.69
880113	140841	537.5	17134.	-5.53	1.30	27.7	-21.20	260.5	19.91	78.41	6.66	-0.03
880113	140855	537.4	17137.	-5.03	1.37	28.0	-20.65	258.4	14.48	78.41	6.62	0.49
880113	140909	537.5	17133.	-4.85	1.40	28.3	-20.37	258.4	14.48	78.44	6.55	-0.43
880113	140923	537.7	17121.	-5.08	1.40	28.9	-20.35	260.3	22.99	78.44	6.48	-0.30
880113	140937	537.8	17116.	-5.05	1.43	29.4	-20.11	260.3	22.99	78.48	6.41	-0.27
880113	140952	538.2	17100.	-5.51	1.41	30.1	-20.26	262.4	10.82	78.48	6.34	0.42
880113	141006	538.6	17080.	-5.45	1.39	29.6	-20.39	258.5	24.28	78.48	6.26	0.37
880113	141020	539.1	17057.	-5.49	1.34	28.5	-20.84	258.5	24.28	78.52	6.23	-0.05
880113	141034	539.5	17037.	-5.65	1.30	28.1	-21.17	264.0	16.32	78.55	6.16	-0.49
880113	141048	540.0	17013.	-5.55	1.29	27.8	-21.21	264.0	16.32	78.55	6.16	-0.59
880113	141102	540.9	16972.	-7.01	1.13	27.3	-22.69	261.3	16.80	78.59	6.05	-0.77
880113	141116	541.5	16941.	-7.86	1.06	27.2	-23.44	264.7	7.52	78.62	5.98	-1.22
880113	141130	542.1	16914.	-8.34	1.02	27.2	-23.86	264.7	7.52	78.66	5.87	-0.97
880113	141144	542.8	16883.	-8.90	0.97	27.2	-24.37	260.7	22.74	78.70	5.80	-0.24
880113	141158	543.5	16849.	-9.17	0.96	27.4	-24.50	260.7	22.74	78.70	5.76	0.45
880113	141212	544.6	16796.	-9.62	0.92	27.3	-24.92	261.6	15.97	78.70	5.72	-1.42
880113	141226	545.1	16772.	-10.01	0.90	27.6	-25.16	264.4	16.58	78.77	5.62	-0.29
880113	141240	545.9	16737.	-10.14	0.90	27.8	-25.19	264.4	16.58	78.77	5.58	0.84
880113	141254	546.9	16692.	-10.34	0.89	28.2	-25.20	261.6	17.05	78.80	5.51	-0.48
880113	141308	547.7	16651.	-10.50	0.88	28.3	-25.30	261.6	17.05	78.84	5.40	-0.03
880113	141322	548.7	16609.	-10.67	0.87	28.4	-25.41	261.6	17.58	78.88	5.36	-0.50
880113	141336	549.6	16568.	-10.84	0.86	28.3	-25.62	265.0	16.08	78.91	5.29	-0.55
880113	141350	550.2	16538.	-10.90	0.85	28.1	-25.72	265.0	16.08	78.95	5.22	-0.73
880113	141404	551.2	16494.	-10.89	0.84	28.0	-25.78	261.5	19.11	78.98	5.18	-1.37
880113	141418	551.8	16463.	-10.99	0.83	27.7	-25.97	261.5	19.11	78.98	5.11	-0.50
880113	141432	552.7	16422.	-10.94	0.82	27.3	-26.08	261.5	19.64	79.02	5.04	-0.75
880113	141446	553.2	16399.	-10.74	0.82	27.0	-26.04	270.1	13.95	79.09	5.00	-1.20
880113	141500	553.8	16374.	-10.72	0.82	27.0	-26.01	270.1	13.95	79.09	4.93	-0.43
880113	141514	554.2	16357.	-10.49	0.82	26.7	-25.95	279.8	25.67	79.45	4.90	-0.07
880113	141528	555.1	16314.	-10.25	0.84	26.8	-25.68	279.8	25.67	79.45	4.82	-0.70
880113	141542	555.6	16294.	-8.87	0.95	27.0	-24.41	259.5	11.87	79.45	4.79	-0.94
880113	141556	555.9	16278.	-7.90	1.00	26.6	-23.75	262.4	17.86	79.49	4.75	-0.73
880113	141610	555.9	16277.	-7.56	1.01	26.2	-23.62	262.4	17.86	79.49	4.68	-0.26
880113	141624	556.9	16231.	-7.64	1.01	26.3	-23.64	257.4	26.39	79.49	4.64	-0.71
880113	141638	557.1	16225.	-8.19	0.97	26.3	-24.09	257.4	26.39	79.49	4.57	-0.70
880113	141652	557.6	16203.	-8.95	0.91	26.4	-24.73	262.9	16.04	79.49	4.57	-0.72
880113	141706	558.1	16176.	-9.44	0.88	26.5	-25.09	259.5	5.15	79.49	4.54	-1.17
880113	141720	558.2	16174.	-9.62	0.87	26.6	-25.21	259.5	5.15	79.49	4.50	0.35
880113	141734	558.8	16145.	-9.87	0.86	26.8	-25.36	259.5	31.80	79.49	4.43	-0.04
880113	141748	559.4	16119.	-9.84	0.86	26.7	-25.38	259.5	31.80	79.45	4.39	-0.09
880113	141802	560.4	16072.	-9.83	0.86	26.7	-25.35	253.1	8.85	79.45	4.32	-0.51
880113	141816	561.2	16036.	-9.65	0.88	26.8	-25.15	259.5	20.63	79.45	4.28	-0.46
880113	141831	562.0	15999.	-9.72	0.87	26.8	-25.23	259.5	20.63	79.45	4.25	-1.18
880113	141845	563.1	15952.	-8.59	0.94	26.7	-24.27	259.5	2.81	79.45	4.18	-1.39
880113	141859	564.3	15898.	-7.65	1.01	26.6	-23.50	259.5	2.81	79.42	4.14	-1.18
880113	141913	565.4	15847.	-7.26	1.05	26.8	-23.10	257.1	25.09	79.42	4.14	-0.71
880113	141927	566.5	15796.	-7.16	1.08	27.5	-22.72	256.8	22.73	79.38	4.03	-0.94
880113	141941	567.8	15739.	-7.02	1.11	28.0	-22.38	256.8	22.73	79.38	4.00	-1.11
880113	141955	569.3	15671.	-6.80	1.14	28.5	-22.00	259.4	13.67	79.38	3.92	-1.86

DATE	TMDAY	PR=MB	PHT=F	DT=DC	MR=GM	RH=PC	DW=DC	BD=DG	BS=MS	AZ=DG	EL=DG	AR=MS
880113	142009	570.7	15607.	-6.59	1.18	28.9	-21.67	259.4	13.67	79.38	3.89	-2.69
880113	142023	571.6	15567.	-6.14	1.23	29.1	-21.18	259.4	25.07	79.38	3.82	-2.02
880113	142037	573.1	15503.	-6.07	1.25	29.6	-20.94	259.4	11.35	79.38	3.78	-2.29
880113	142051	574.2	15453.	-5.56	1.32	30.1	-20.30	259.4	11.35	79.38	3.74	-1.16
880113	142105	574.8	15424.	-4.72	1.41	30.3	-19.47	264.6	11.65	79.42	3.71	0.36
880113	142119	576.0	15371.	-4.12	1.48	30.4	-18.91	264.6	11.65	79.42	3.64	-0.93
880113	142133	577.2	15319.	-3.95	1.50	30.5	-18.73	268.8	19.92	79.52	3.60	-1.54
880113	142147	577.8	15288.	-4.37	1.45	30.4	-19.12	261.3	18.12	79.56	3.53	-1.63
880113	142201	578.6	15256.	-4.88	1.38	30.[illegible]	-19.68	261.3	18.12	79.56	3.53	-0.06
880113	142215	579.3	15222.	-5.70	1.27	29.6	-20.61	259.6	4.90	79.56	3.49	-0.02
880113	142229	580.3	15180.	-6.42	1.18	29.0	-21.47	259.6	4.90	79.60	3.46	-1.09
880113	142243	581.3	15135.	-6.37	1.17	28.8	-21.50	271.7	5.27	79.60	3.42	-2.20
880113	142257	581.5	15127.	-6.10	1.15	27.7	-21.70	262.1	25.67	79.63	3.38	0.43
880113	142311	581.6	15122.	-6.14	1.13	27.2	-21.95	262.1	25.67	79.63	3.35	1.91
880113	142325	582.5	15082.	-6.28	1.12	27.4	-21.99	259.6	9.31	79.63	3.35	-0.65
880113	142339	583.3	15047.	-6.34	1.12	27.5	-22.01	259.6	9.31	79.63	3.31	-0.69
880113	142353	583.5	15037.	-6.50	1.11	27.8	-22.03	266.2	9.90	79.67	3.31	1.06
880113	142407	583.8	15026.	-6.93	1.09	28.0	-22.30	254.8	13.53	79.63	3.28	0.84
880113	142421	584.5	14995.	-7.37	1.06	28.2	-22.60	254.8	13.53	79.63	3.24	0.17
880113	142435	585.0	14972.	-7.74	1.05	28.8	-22.68	259.6	24.35	79.63	3.20	-0.41
880113	142449	585.3	14961.	-7.88	1.03	28.7	-22.85	259.6	24.35	79.60	3.17	-0.87
880113	142503	585.8	14937.	-8.07	1.02	28.8	-22.99	255.0	14.55	79.60	3.13	-0.87
880113	142517	586.2	14920.	-8.28	0.99	28.6	-23.26	253.3	10.68	79.56	3.13	-0.81
880113	142531	586.4	14912.	-8.53	0.99	29.1	-23.27	253.3	10.68	79.52	3.10	0.41
880113	142545	586.9	14888.	-8.61	1.01	30.0	-23.02	257.6	34.75	79.52	3.06	-0.04
880113	142559	587.6	14860.	-8.48	1.04	30.5	-22.71	257.6	34.75	79.49	3.02	0.20
880113	142613	588.6	14818.	-7.60	1.13	30.9	-21.77	250.1	7.33	79.49	3.02	-0.26
880113	142627	589.5	14777.	-7.07	1.18	31.1	-21.26	259.5	6.98	79.49	2.99	-0.50
880113	142642	590.2	14746.	-6.50	1.24	31.3	-20.69	259.5	6.98	79.49	2.95	-0.26
880113	142656	591.6	14686.	-6.08	1.26	31.0	-20.43	259.5	28.25	79.49	2.92	-1.26
880113	142710	591.8	14678.	-5.47	1.31	30.6	-20.01	259.5	28.25	79.49	2.88	0.04
880113	142724	593.3	88888888	88888888	88888888	88888888	88888888	88888888	88888888	79.49	2.84	88888888
880113	142738	594.1	14578.	-5.56	1.31	30.8	-20.01	259.5	30.05	79.49	2.81	-1.00
880113	142752	595.8	14504.	-5.70	1.31	31.4	-19.94	259.5	30.05	79.52	2.77	-0.16
880113	142806	597.2	14445.	-5.58	1.34	32.0	-19.62	261.8	30.88	79.52	2.74	-4.51
880113	142820	597.8	14417.	-5.31	1.42	33.0	-19.00	261.8	30.88	79.52	2.70	-2.51
880113	142834	599.2	14359.	-5.12	1.45	33.5	-18.67	79.5	14.33	79.52	2.66	-1.64
880113	142848	600.1	14319.	-4.82	1.50	33.8	-18.30	261.5	37.15	79.56	2.63	-1.72
880113	142902	600.7	14294.	-4.38	1.57	34.2	-17.76	261.5	37.15	79.56	2.59	-0.09
880113	142916	602.4	14222.	-4.50	1.56	34.4	-17.80	251.9	9.66	79.52	2.59	-2.15
880113	142930	602.9	14198.	-4.48	1.57	34.7	-17.70	251.9	9.66	79.52	2.56	-0.47
880113	142944	604.1	14147.	-4.60	1.55	34.7	-17.79	259.5	24.62	79.56	2.52	-2.61
880113	142958	605.3	14097.	-4.56	1.55	34.6	-17.79	266.7	10.43	79.56	2.48	-1.29
880113	143012	606.6	14042.	-4.52	1.55	34.4	-17.82	266.7	10.43	79.63	2.45	-2.10
880113	143026	607.4	14005.	-4.47	1.54	34.1	-17.88	273.5	10.94	79.63	2.45	-2.32
880113	143040	608.5	13959.	-4.32	1.53	33.7	-17.89	273.5	10.94	79.63	2.38	-2.72
880113	143054	609.8	13905.	-4.05	1.55	33.5	-17.73	262.0	32.44	79.67	2.38	-1.74
880113	143108	610.7	13867.	-4.02	1.54	33.2	-17.81	259.7	6.20	79.67	2.34	-1.52
880113	143122	611.7	13824.	-3.95	1.53	33.0	-17.81	259.7	6.20	79.74	2.30	-2.22
880113	143136	611.9	13817.	-3.80	1.53	32.6	-17.83	283.1	6.75	79.74	2.27	1.22
880113	143150	613.5	13749.	-3.84	1.50	32.0	-18.06	283.1	6.75	79.81	2.27	-1.43
880113	143204	614.9	13688.	-3.39	1.52	31.6	-17.83	262.8	52.00	79.81	2.23	-3.29
880113	143218	615.0	13687.	-3.30	1.53	31.6	-17.75	79.8	22.17	79.81	2.23	1.03
880113	143232	88888888	88888888	-3.13	88888888	88888888	88888888	88888888	88888888	79.88	2.20	88888888
880113	143246	615.9	13647.	-4.49	1.36	30.7	-19.10	8888.9	8888.88	79.88	2.16	-0.15
880113	143300	617.8	13568.	-3.68	1.42	30.3	-19.57	8888.9	8888.88	79.88	2.12	-2.08

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  DATE    TMDAY    PR=MB   PHT=F    DT=DC    MR=GM    RH=PC    DW=DC    BD=DG    BS=MS    AZ=DG    EL=DG    AR=MS
 880113  143314   618.7   13529.    -3.71     1.42     30.3   -18.58    263.7    30.96    80.10     2.12    -1.40
 880113  143328   617.9   13561.    -3.98     1.37     29.9   -18.99     48.6    13.41    80.10     2.12     2.01
 880113  143342   618.5   13536.    -3.56     1.41     29.8   -18.68     48.6    13.41    80.14     2.09     3.48
 880113  143356   619.1   13513.    -3.48     1.41     29.6   -18.67   8888.9  8888.88    80.17     2.09    -0.52
 880113  143410   620.0   13475.    -3.46     1.41     29.6   -18.64   8888.9  8888.88    80.17     2.05    -0.04
 880113  143424   621.6   13408.    -3.32     1.41     29.4   -18.60    266.2    19.97    80.21     2.02    -3.15
 880113  143438   621.7   13405.    -3.40     1.40     29.3   -18.71    269.7     8.66    80.24     2.02    -2.26
 880113  143452   622.1   13388.    -3.46     1.39     29.3   -18.76    269.7     8.66    80.28     1.98    -0.26
 880113  143506   622.8   13360.    -3.74     1.38     29.7   -18.87    183.3   110.91    72.76     1.98    -1.46
 880113  143520   623.7   13323.    -3.68     1.37     29.5   -18.86    183.3   110.91    62.24     1.98    -1.24
 880113  143534   624.5   13288.    -3.67     1.36     29.2   -18.98    157.6   607.99    62.28     1.91    -1.26
 880113  143548   625.8   13232.    -3.92     1.33     29.2   -19.20    245.6    49.70    62.32     1.91    -3.10
 880113  143602   627.0   13183.    -4.89     1.22     29.0   -20.13    245.6    49.70    62.32     1.87    -1.11
 880113  143616   628.6   13120.    -5.38     1.19     29.3   -20.43    261.8     4.38    62.35     1.87    -1.26
 880113  143630   630.3   13051.    -5.57     1.18     29.7   -20.45    261.8     4.38    62.39     1.84    -3.03
 880113  143644   631.8   12987.    -5.63     1.17     29.5   -20.60    250.4    10.47    62.39     1.84    -3.42
 880113  143658   633.3   12928.    -5.70     1.16     29.6   -20.59     45.1     9.86    62.46     1.80     0.20
 880113  143712   635.5   12839.    -5.71     1.15     29.3   -20.72     45.1     9.86    62.50     1.80    -2.05
 880113  143726   639.1   12691.    -5.35     1.16     29.1   -20.50     60.7    45.58    62.50     1.80    -5.31
 880113  143740   639.9   12662.    -4.72     1.23     29.5   -19.81     60.7    45.58    62.50     1.80    -1.27
                                                                                       ________
 880113  143754   641.3   12603.    -4.49     1.23     28.9   -19.83    107.8  3208.13   -12.53    -0.29    -3.18
 880113  143808   644.5   12476.    -4.31     1.23     28.6   -19.78    173.1  5824.85   -12.53    -0.29     0.53
* 880113    143904    653.9   12102.    -4.06      1.21      28.0    -19.
   122.53   -12.53    -0.32     2.42
  880113    143918    655.7   12030.    -3.02      1.31      28.1    -18.
   77.00    -12.53    -0.32    -1.56
  880113    143932    657.0   11978.    -2.19      1.42      28.7    -17.
   77.00    -12.53    -0.32    -1.19
  880113    143946    658.0   11940.    -1.94      1.47      29.2    -17.
   55.41    -12.53    -0.32     1.45
  880113    144000    660.3   11892.    -1.81      1.50      29.6    -17.
   55.41    -12.53    -0.32  8888.88
  880113    144014    661.9   11784.    -1.78      1.52      30.1    -16.
   67.19    -12.53    -0.32    -2.53
  880113    144028    663.8   11710.    -1.52      1.55      30.2    -16.
   56.71    -12.53    -0.32    -1.13
  880113    144042    664.4   11685.    -1.47      1.50      29.2    -17.
   56.71    -12.53    -0.32    -1.00
  880113    144056 88888888 88888888 88888888 88888888 88888888 8888888
88888888    -12.53    -0.32 88888888
  880113    144110    669.4   11490.    -1.71      1.59      31.7    -16.
   22.81    -12.53    -0.32    -3.00
  880113    144124    666.8   11593.    -2.52      1.57      33.2    -16.
   92.31    -12.53    -0.32     3.53
  880113    144138    673.7   11369.    -1.50      1.74      34.4    -15.1
 8888.88    -12.53    -0.32  8888.88          LAST USEABLE
  880113    144152 88888888 88888888    -2.78 88888888 88888888 8888888
88888888    -12.53    -0.32 88888888
  880113    144206 88888888 88888888    -2.99 88888888 88888888 8888888
88888888    -12.53    -0.32 88888888
  880113    144220 88888888 88888888    -3.49 88888888 88888888 8888888
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  880113    144234 88888888 88888888    -1.86 88888888 88888888 8888888
88888888    -12.53    -0.32 88888888
  880113    144248 88888888 88888888 88888888 88888888 88888888 8888888
88888888    -12.53    -0.32 88888888
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NOTES ON AIR SONDE DATA FROM FLIGHT 2

- Columns are rearranged in comparison to flight 1, but most headings are unchanged.
- The height is given in column 4 labeled "PHT=F" and is given in feet above mean sea level. The launch site was at approximately 6570 ft MSL.
- Rise rate in m/s is given in the last column. The loss of the payload is apparent in the rise rate given at 13:39:51 and thereafter.
- Because the balloon went to high altitude, we were able to track it through almost its entire flight till a few minutes before touchdown more than 80 km away.